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EDITOR

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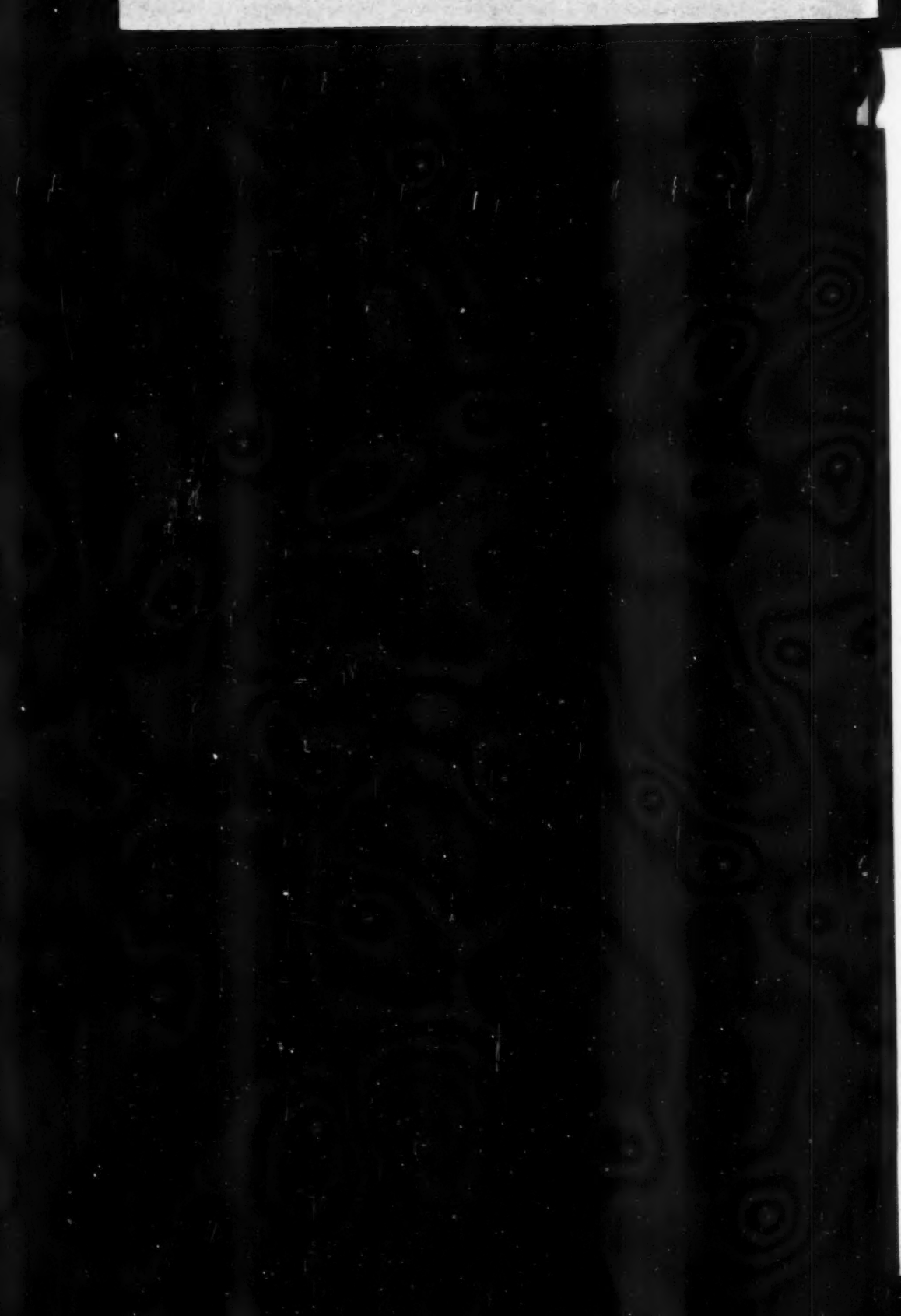

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AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

JANUARY-FEBRUARY 1924

A STUDY OF THE PRESENT CALIFORNIA OIL SITUATION[1]

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The oil industry wants California to answer two vital questions, and California is just as interested to know the answers to the questions as is the oil industry. These two questions are, first, "When has, or when will California reach the peak of the present overproduction of oil," and, second, "When will the consumption of California and the western seaboard equal or exceed the production of California? The oil industry wants answers to these questions, because California production now affects the oil markets of the world. California desires answers in order that justification may be had for the policy of storing oil, and building new storage. If an excess of oil for storage is to continue indefinitely, no organization is large enough to meet the situation. If the condition promises to have an end, it is important for California that as much oil be retained within the state as possible. Neither the industry nor California can continue indefinitely under the present load. The purpose of this paper is to discuss these two questions and consider the factors bearing upon them.

Careful study leads to the conclusion that California is producing its maximum at the present time (September, 1923), and that there will be no surplus production during the latter part of 1924, even

[1] Read before the Association, Los Angeles, September, 1923. Manuscript received by the Editor, December 22, 1923.

assuming that, beginning in January, oil now shut in in the older fields is produced as freely as oil is now produced in the newer fields. These conclusions are based upon a study of conditions in all of the fields. Because the Santa Fe Springs, Signal Hill, and Huntington Beach fields are of more interest at present, they will be discussed more fully.

The production of the older fields in this state can be estimated with reasonable accuracy because there is little flush production involved. Table I gives data relative to these fields.

TABLE I

PRODUCTION OF AND DATA RELATIVE TO OLDER CALIFORNIA FIELDS

Field	No. of Producing Wells	Approx. Drainage Area per Well in Acres	Remarks (Figures for wells shut in are only approximate)	July, 1922, Daily Prod. in Bbls.	April, 1923, Daily Prod. in Bbls.	Sept., 1923, Daily Prod. in Bbls.
Kern River	2,166	2.4	Settled production. Few wells shut in.	19,500	20,193	19,003
McKittrick	277	2.0	Settled production. Few wells shut in.	6,000	6,221	6,070
Midway-Sunset	2,078	5.0	464 wells shut in. Some drilling possible. Slow decline.	73,200	70,704	74,645
Elk Hills	94	8.0	59 wells shut in. Additional drilling possible.	23,700	20,806	22,321
Lost Hills–Belridge	284	4.5	220 wells shut in. Little drilling possible.	3,800	6,408	3,792
Coalinga	676	6.1	543 wells shut in.	13,211	13,236	14,198
Santa Maria	327	10.5	Settled production. No new drilling	6,400	8,858	8,365
Summerland	135					
Watsonville	6					
Wheeler Ridge	1	.....	Future uncertain. New drilling possible.	285	219	509
Newhall and Ventura Co.	538	Scattered	Slow, well controlled increase.	10,632	9,940	10,097
Old Salt Lake	276	2.5	No new drilling. Many small producers scattered.	2,500	3,369	3,179
L. A. City	322	Scattered				
Montebello–Whittier	300	Scattered	Steady but gradual decline. Some production shut in.	12,000	15,118	12,118
Coyote	111	5.0	117 wells shut in.	19,396	11,619	2,834
Fullerton	384	.....	Future uncertain. Deep sand discovered.	11,200	11,225	10,780
Richfield	176	4.4	New deep sand contains only heavy oil.	16,500	18,020	15,090
Totals	8,151	.....	.....	218,324	215,936	203,001

There are three new fields in the making, namely, Wheeler Ridge, Torrance-Redondo, and Compton. Each of these has a certain potential value, which is summed up in the following paragraphs:

Wheeler Ridge is a new field at the southern end of the San Joaquin Valley, having a very closely compressed anticline. Some new production will be secured, but thus far the field has not indicated that it will have a very large production. One well was completed in July with an initial daily production of 285 barrels. Only 9 wells are drilling, with one new rig erected. Estimated January, 1924, production is 30 barrels a day; estimated December, 1924, production is 400 barrels a day.

The comparatively new Torrance-Redondo field has 39 producing wells from which 6,000 barrels per day are secured, the best well only producing 900 barrels per day. If no larger wells are secured, the field will hardly make up for the decline in production of older fields. Most of the land is held in large tracts and by large companies which will not drill it too rapidly. It is possible that deeper sands will be found, and that when the crest of the structure is located, larger wells will be secured. Estimated January, 1924, production is 8,000 barrels a day: estimated December, 1924, production is 25,000 barrels a day.

The Compton field, the latest discovery in southern California, will unquestionably be a companion to Huntington Beach and Signal Hill, for geological conditions are much the same in all three fields. Dominguez Hill, on which the discovery well is located, is a much more prominent topographic feature than the elevation at Huntington Beach. The discovery well came in at 950 barrels per day, and has since increased in production to about 1,300 barrels. Deeper sands may be expected, and also larger wells. Estimated January, 1924, production is 1,000 barrels a day; estimated December, 1924, production is 10,000 barrels a day.

The presence of the undeveloped fields at Wheeler Ridge, Torrance, and Compton will not affect the present peak of production. Santa Fe Springs required from October 28, 1921, to January, 1923, to reach a daily production of 90,000 barrels; Long Beach required from June, 1921, to January, 1923, to produce 100,000 barrels per day; Huntington Beach required from June, 1920, to January, 1923, to produce 80,000 barrels per day (Fig. 1.).

From the foregoing data it will be seen that more than a year's time was necessary to bring each of the big southern California fields to a production of 100,000 barrels. The cause of the rapid increase in production from these three fields was the location of each of them in an area consisting almost entirely of small parcels of land. This resulted in close spacing of wells, and rapid competitive drilling. Even if the new areas were drilled as rapidly, it would take a year before they would be factors of material importance. Fortunately each of these three fields contains many large tracts of land and the companies holding them have always conducted their operations conservatively and with relation to the general oil situation. The fields will not be drilled rapidly and will not reach their peak of production for at least two years. When this peak is reached, it will not be as high as Santa Fe Springs and Signal Hill.

As will be shown below, the production of California will probably fall below its indicated future consumption. The difference between consumption and production will represent a margin of safety for any intensive development which may occur in new fields where small parcels of land induce rapid drilling.

The most difficult part of this study is to determine the future production of Santa Fe Springs, Signal Hill, and Huntington Beach. Among several methods of estimating their future production three have been used.

The first, or method A, bases estimates on the time of completion, initial production, and decline of each well as determined from a decline curve. The second, or method B, makes estimates by multiplying the daily average production per well by the total number of producing wells. Each of these units is determined by projecting curves of the past into the future. The third, or method C, consists first of estimating for each month the average rate of decline of wells producing at the first of the month, and adding the estimated new monthly production after deducting one-fourth of the new production to represent its decline during the month. In order to determine the rate of decline of existing production as of the first of the month, the decline of production existing on the first of April and each succeeding month has been segregated. This

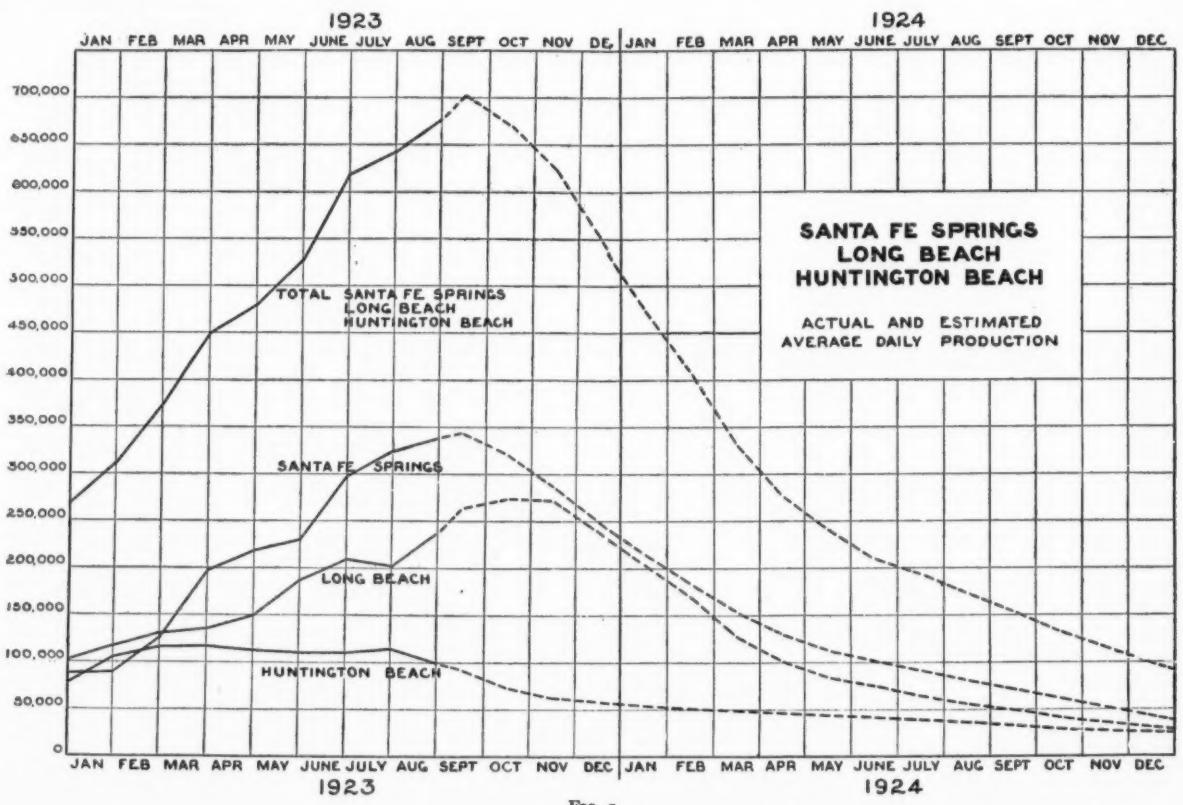

1923
1924
JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT NOV DE, JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT NOV DEC
700,000
650,000
600,000
550,000
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
SANTA FE SPRINGS
LONG BEACH
HUNTINGTON BEACH
ACTUAL AND ESTIMATED
AVERAGE DAILY PRODUCTION
TOTAL SANTA FE SPRINGS
LONG BEACH
HUNTINGTON BEACH
SANTA FE SPRINGS
LONG BEACH
HUNTINGTON BEACH
JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT NOV DEC JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT NOV DEC
1923
1924

FIG. 1

shows that as to each of such items, the rate of decline after the first month is more gradual than during the first month. The existing production as of September 1, was declined during the next four weeks at a rate suggested by the actual decline of the production existing on the first of the several preceding months. The amount of the estimated new production was secured by projecting the average daily initial production per new well into the future and multiplying it by the total number of new wells each week. This last item was an average secured by plotting the number of new wells completed in previous months. The product secured by multiplying the average daily production per new well by the number of new wells per week, represents the total new production per week. The total new production per week in weeks past was also secured from a curve and by trial, the future new production was made to agree with the product secured by considering the other two items separately.

Each of these methods is subject to certain criticisms. Method A almost invariably gives estimates higher than actual production. This is due to the fact that every well is assumed by this method to be completed. The rate of drilling may be assumed to be slower than actual practice to adjust this feature and to take care of drilling delays. The effect of assuming that every well will be completed, results in having too many producers. In attempting to estimate what new wells will produce, one is prone to be too conservative on the wells to come in within a few months, and not conservative enough on the wells to come in several months hence. This makes the results of method A appear very conservative the first month or two, and too high later. It is very difficult, where drilling is close, to estimate what new production will be three or four months in the future. While estimates made by this method in the past have usually approximated actual production, it has usually been the practice to revise at short intervals estimates made under method A. The method requires a most intimate knowledge of conditions existing in the field, is cumbersome because of the large number of wells to be considered, and does not take into account difficulties such as casing trouble and the encroachment of water

which may arise with producing wells. Method A has appeared attractive and reliable because the production of early producers was estimated lower than these wells came in. The wells that failed to come in were not missed, since the total of actual production later recorded agreed fairly well with the estimate of method A.

Method B is the quickest in making a forecast, since only two elements are considered—average daily production per well and number of producing wells. Thus far, in these three fields, the change in the two factors mentioned has varied from week to week less than any others. More units are involved and any changes in the future will therefore be less marked. Main objection to the method is that it must assume fundamentally that conditions will continue in the future as they have in the past. This cannot be so, for eventually the field will be drilled up, and problems which formerly were negligible because of the high gas pressure will more and more assert themselves. Since the amount of probable future production promises to be less and less, the ability of the small operator to re-finance by paying out of oil becomes less certain, which means that more drilling wells will fail to be completed than in the past. Another objection is the fact that it does not take fully into consideration water problems which are now beginning and promise to be very important in the future.

Method C is somewhat longer than B but is very much shorter than A. If the southern California fields had not been subject to frequent prorating and to partial shutting in of wells, the decline of the production existing at the first of each month would have been more regular. Despite this condition, the rate of decline during the first month for the production existing at the first of April and on the first of months following has been fairly uniform. When there are no more completions, the old production may be expected to decline in subsequent months in much the same manner as did the production of April first and months following. The decline will be less rapid than this, rather than more rapid, for the reason that when a field is fairly well drilled up, the production will be more settled, and each well will decline at a slower rate than it did

in the earlier part of its life. As the old production will in the future be an increasingly larger component, under method C, than the new production, it is clear that the decline of the total production of a field following the first of each future month should be assumed as a less amount than that indicated during the earlier life of the field. In the application of method C on these curves, this element was neglected because it could not be weighed and therefore the same rate of decline following the first of September was applied every four weeks. The other component in method C, new production, shows a greater variation from week to week than any other element. Obviously any attempt to project it into the future will be affected by this condition. The number of new wells completed each week has changed almost as markedly from time to time as the new production has changed. However, as the total new production for the week is estimated by two methods, that is, by considering the new production itself and by multiplying the average daily initial production per new well by the number of new wells per week, some of the disadvantage of this great variation has been eliminated.

In the curves for the three fields which are submitted, the final estimate of average daily production in the future has in most cases been assumed to be less than the figures shown by any of these three methods, in order to give weight to factors which none of the methods are able to consider. These factors are the rapid decline in gas pressure, and the increasing effect which water problems will have in the future.

Santa Fe Springs.—Production in the Santa Fe Springs field has climbed from 86,000 barrels in January, 1923, to a peak of about 350,000 barrels about the first of September (Fig. 2). The increase has not been so regular as it might have been, because some production has been shut in.

Under method A, its peak production would come about November 15, and be 403,000 barrels. This estimate is much too high and will not be attained by the field.

Under method B, a lower estimate is secured. The two components on which this curve is based are average daily production

per well, and the number of producing wells, The average daily production per well rose from 1,250 barrels in January, 1923, to 2,400 barrels in May, and has since declined to 1,600 barrels. A

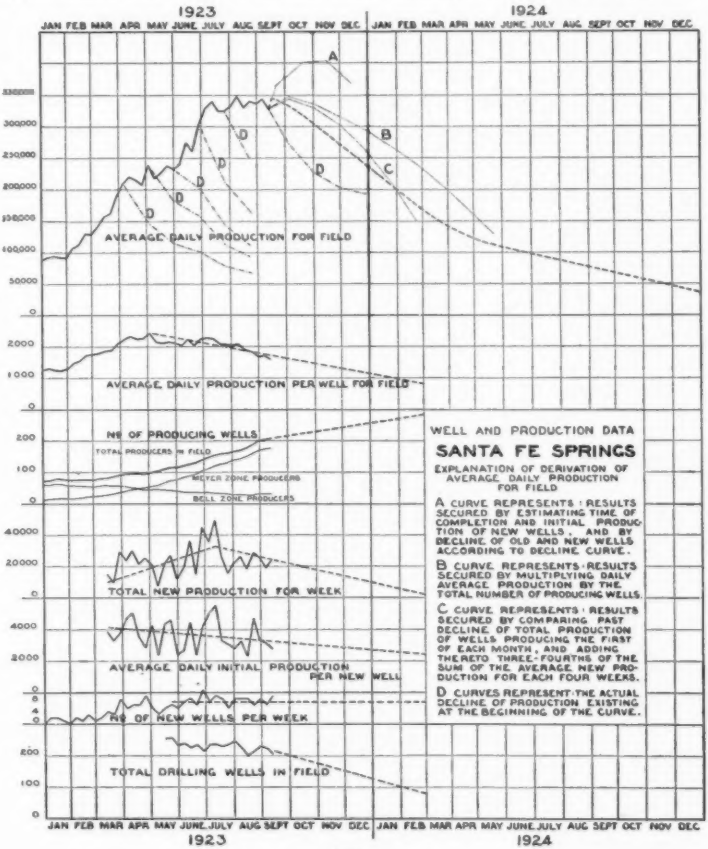

1923
1924
JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT NOV DEC
AVERAGE DAILY PRODUCTION FOR FIELD
AVERAGE DAILY PRODUCTION PER WELL FOR FIELD
NO OF PRODUCING WELLS
TOTAL PRODUCERS IN FIELD
MEYER ZONE PRODUCERS
BELL ZONE PRODUCERS
TOTAL NEW PRODUCTION FOR WEEK
AVERAGE DAILY INITIAL PRODUCTION PER NEW WELL
NO OF NEW WELLS PER WEEK
TOTAL DRILLING WELLS IN FIELD
WELL AND PRODUCTION DATA
SANTA FE SPRINGS
EXPLANATION OF DERIVATION OF AVERAGE DAILY PRODUCTION FOR FIELD
A CURVE REPRESENTS: RESULTS SECURED BY ESTIMATING TIME OF COMPLETION AND INITIAL PRODUCTION OF NEW WELLS, AND BY DECLINE OF OLD AND NEW WELLS ACCORDING TO DECLINE CURVE.
B CURVE REPRESENTS: RESULTS SECURED BY MULTIPLYING DAILY AVERAGE PRODUCTION BY THE TOTAL NUMBER OF PRODUCING WELLS.
C CURVE REPRESENTS: RESULTS SECURED BY COMPARING PAST DECLINE OF TOTAL PRODUCTION OF WELLS PRODUCING THE FIRST OF EACH MONTH, AND ADDING THERETO THREE-FOURTHS OF THE SUM OF THE AVERAGE NEW PRODUCTION FOR EACH FOUR WEEKS.
D CURVES REPRESENT THE ACTUAL DECLINE OF PRODUCTION EXISTING AT THE BEGINNING OF THE CURVE.

FIG. 2

continual decline in the future to 400 barrels by June, 1924, is expected. The number of producing wells has increased regularly from 70 wells in January, 1923, to 200 wells at the first of September. An intimate knowledge of the field leads to the belief that the num-

ber of producing wells will not increase indefinitely, but when approximately 320 wells have come on production, new wells put on production will only take the place of old wells that go off production. Both of these assumptions are very optimistic. Method B shows a daily production peak of 347,000 barrels near the end of September and a gradual decline thereafter as indicated in Table II. This estimate is too high for the reason that when wells stop flowing, pumping will not always follow and continue regularly. While the success of pumping at Santa Fe Springs is by no means

TABLE II

ESTIMATES OF DAILY PRODUCTION OF THE SANTA FE SPRINGS FIELD, IN BARRELS

Months	Method A	Method B	Method C	Modified
September, 1923	.....	.....	327,000	344,000
October	.....	.....	343,000	320,000
November	403,000	333,000	315,000	287,000
December	.....	.....	281,000	252,000
January, 1924	.....	274,000	230,000	216,000
February	.....	.....	173,000	184,000
March	.....	213,000	.....	154,000
April	.....	.....	.....	130,000
May	.....	133,000	.....	112,000
June	.....	.....	.....	102,000
July	.....	.....	.....	92,000
August	.....	.....	.....	82,000
September	.....	.....	.....	72,000
October	.....	.....	.....	62,000
November	.....	.....	.....	52,000
December	.....	.....	.....	42,000

assured, wells are now pumped in California from a depth of 4,000 feet by using two pump barrels, one at the bottom of the hole and one half way up the hole. If fluid levels in Santa Fe Springs wells are found between 3,000 and 4,000 feet, the wells probably will be pumped. It may be assumed that wells will go off production as flowing wells at about 200 to 300 barrels, and will then begin as pumpers at about the same rate. Such an assumption promises more production than will probably be secured, and the same applies to pumping deep wells at Signal Hill and Huntington Beach.

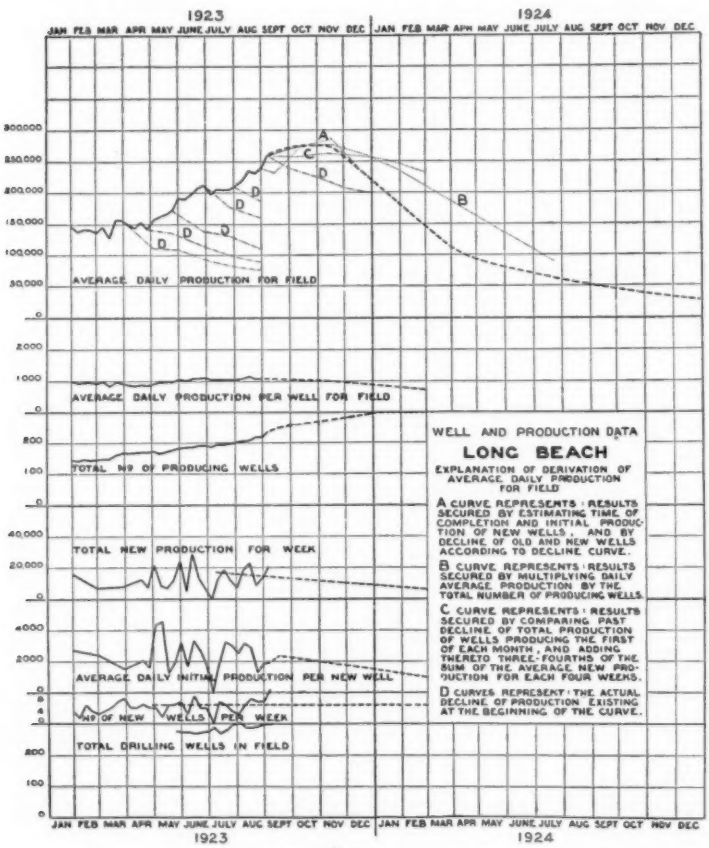
One of the components of method C is a study of old production existing on the first of each calendar month. In the Santa Fe

Springs field, this old production has declined about 20 per cent during the calendar month. The new production per week at Santa Fe Springs has varied from 9,000 barrels per week in April to 22,000 barrels per week in May, with a peak of 50,000 barrels per week in June. Its decline has been assumed to be regular, so that new production per week in October may be anticipated at 20,000 barrels, in January, 1924, 9,500 barrels, and in March 2,000 barrels. The number of new wells per week averages 7. The average daily initial production for each well has varied from 3,900 barrels in March, 1923, to a peak of 5,500 barrels in July. It will decline as follows: September, 3,200 barrels; November, 2,900 barrels; January, 1924, 2,650 barrels. The results of method C show a change of production in Santa Fe Springs by months as indicated by Table I.

Most recent developments in the western part of the Santa Fe Springs field indicate that no wells producing more than 6,000 or 7,000 barrels may be expected in the future. The lower limits of the oil zone have been proven by finding edge water 300 feet below the top of the zone. The zone is hardly more than 300 feet thick, instead of the 600 feet occurring on the crest of the fold. Deep wells, even near the crest of the structure are already affected by edge water in the lower sands. The town-site area is showing a marked decrease in gas pressure. It is thought that the partially drilled northwest end of the field, will lose part of its gas by migration to the town site. Because of these elements which none of the curves take sufficiently into consideration, the final estimate of the daily average production for the Santa Fe Springs field is as shown in Table I.

Signal Hill.—The three methods give closer results for the Signal Hill field, Long Beach (Fig. 3), than at Santa Fe Springs. Computations using method A are shown in the first column of Table II. In applying method B, it may be noted that the daily average production per well for this field has continued very uniformly at approximately 1,000 barrels since last January, 1923. By February, 1924, this will have probably declined to 800 barrels, and by May will be 530 barrels. The number of new wells has been assumed to increase regularly until 300 wells are secured in January, after which

it was felt that new wells would only replace old wells lost. Judging by the number of wells that have dropped out the foregoing assumptions seem liberal.


1923
1924
JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT NOV DEC
AVERAGE DAILY PRODUCTION FOR FIELD
AVERAGE DAILY PRODUCTION PER WELL FOR FIELD
TOTAL NO OF PRODUCING WELLS
TOTAL NEW PRODUCTION FOR WEEK
AVERAGE DAILY INITIAL PRODUCTION PER NEW WELL
NO OF NEW WELLS PER WEEK
TOTAL DRILLING WELLS IN FIELD
WELL AND PRODUCTION DATA
LONG BEACH
EXPLANATION OF DERIVATION OF AVERAGE DAILY PRODUCTION FOR FIELD
A CURVE REPRESENTS: RESULTS SECURED BY ESTIMATING TIME OF COMPLETION AND INITIAL PRODUCTION OF NEW WELLS, AND BY DECLINE OF OLD AND NEW WELLS ACCORDING TO DECLINE CURVE.
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D CURVES REPRESENT: THE ACTUAL DECLINE OF PRODUCTION EXISTING AT THE BEGINNING OF THE CURVE.

FIG. 3

In formulation of estimates by method C it was found that in this field the production existing on the first of each calendar month declined during that month at the rate of approximately 10 per cent. The total daily new production each week has increased from 12,000

barrels in February, 1923, to 14,000 barrels in May, to a peak of 25,000 barrels in June, and has since declined to 14,000 barrels in September. The number of new wells has varied from week to week, but 6 wells is an average figure per week. The average daily initial production for new wells in this field has risen irregularly from 2,600 barrels in February, 1923, to 3,400 barrels in May, and 3,000 barrels in July, and has since declined to 2,360 barrels in September. This indicates that the daily average production for a new well will be about 2,200 barrels in October, 1,300 barrels in January, and 800 barrels in March, 1924. The estimates of method C eventually rise above those of methods A and B, primarily because the old production existing at the first of each calendar month had declined very slowly, as wells have been partly shut in ever since spring. In the future, however, with the wells flowing wide open, old production will decline much more rapidly than it has in the past. When this condition does occur, and is applied in constructing a curve under method C, the results may be much less than those shown by the present C curve.

The Signal Hill field has a remarkably thick oil zone and protection against the infiltration of water has not been based on uniform shut-offs. Only one shut-off was necessary at the top of the oil zone. Edge water has been avoided in the past by merely drilling deeper, cementing another string of pipe, and bringing in a well. But this cannot go on indefinitely and eventually the field will have to pay for such practice. Water will be able to migrate from shallow wells to deep wells with shallow second shut-offs which will cause a more rapid decline in old production than has been assumed, and may even result in destroying new production. The desire to drill deep has existed in all of the fields; a result of the theory that the deeper a well was drilled, the better the production. At Huntington Beach and Santa Fe Springs, even in the town site, this resulted in securing edge water in the lowest sands of the zone. At Signal Hill, the enthusiasm for deep drilling is still manifest. The operator who fails to get to the supposed bottom of the zone because of the physical condition of his well may eventually be more fortunate than his neighbor who bores his way down. All of these facts will tend to make the results outlined above under methods A, B, and C

entirely too high. Every favorable factor that can give hope of increase has been considered and the remaining factors will lessen production. In view of this condition, it has been assumed that the daily average production of the field by months will be as indicated in the last column of Table III.

TABLE III

ESTIMATES OF DAILY PRODUCTION OF THE SIGNAL HILL FIELD, IN BARRELS

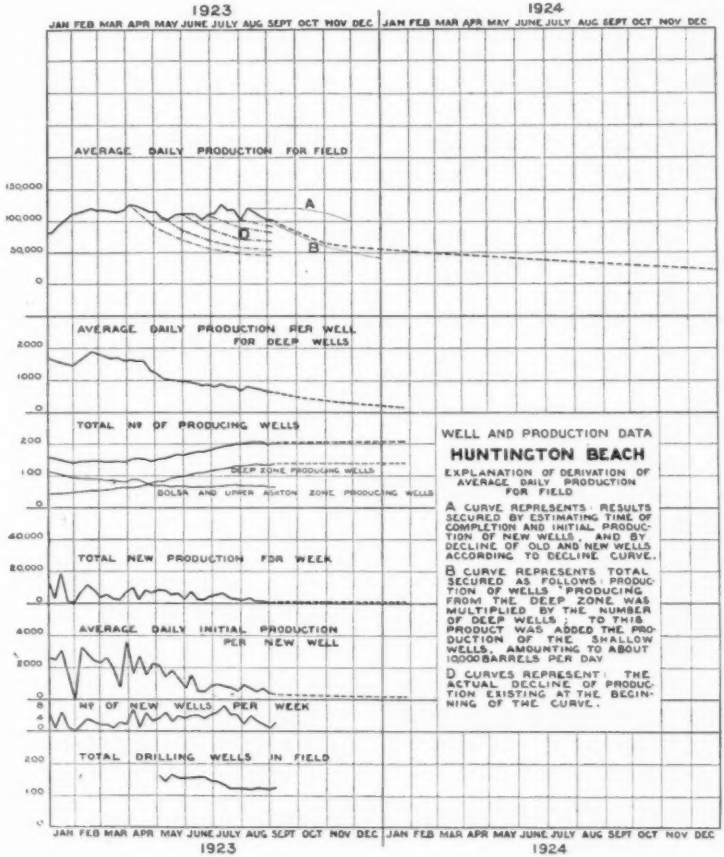
Months	Method A	Method B	Method C	Modified
September, 1923	232,310	266,680	258,000	264,000
October	266,680	275,000	257,000	274,000
November	285,890	277,000	263,000	272,000
December	242,195	266,000	259,000	240,000
January, 1924	.....	246,000	252,000	205,000
February	.....	230,000	245,000	171,500
March	.....	200,000	228,000	128,000
April	.....	174,000	.....	101,000
May	.....	147,000	.....	84,000
June	.....	121,000	.....	75,000
July	.....	94,000	.....	64,000
September	.....	.....	.....	48,500
October	.....	.....	.....	42,500
November	.....	.....	.....	36,000
December	.....	.....	.....	31,000

Huntington Beach.—The Huntington Beach field increased its production from 80,000 barrels in January, 1923, to 125,000 barrels in March (Fig. 4). Thereafter part of its production was always shut in, so that the field has only produced from 100,000 to 125,000 barrels per day.

Under method A, it appears that production in the field will continue about 100,000 barrels until November, but this conclusion is not supported by curves drawn under the other methods, and by field conditions.

The average daily production per well for deep wells declined fairly regularly from 1,900 barrels per day in February, 1923, to 600 barrels per day in September. This decline should continue in the same way until the wells reach the pumping stage, when it should be more gradual. There are about 66 relatively shallow wells, producing from the Bolsa zone and the upper part of the Ashton zone, at a rate of about 10,000 barrels per day. The curve

under method B was drawn on the deep wells, and then 10,000 barrels per day were added to show the curve on the diagram.


1923
1924
JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT NOV DEC
AVERAGE DAILY PRODUCTION FOR FIELD
A
D
B
AVERAGE DAILY PRODUCTION PER WELL FOR DEEP WELLS
TOTAL Nº OF PRODUCING WELLS
DEEP ZONE PRODUCING WELLS
BOLSA AND UPPER ASHTON ZONE PRODUCING WELLS
TOTAL NEW PRODUCTION FOR WEEK
AVERAGE DAILY INITIAL PRODUCTION PER NEW WELL
Nº OF NEW WELLS PER WEEK
TOTAL DRILLING WELLS IN FIELD
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A CURVE REPRESENTS RESULTS SECURED BY ESTIMATING TIME OF COMPLETION AND INITIAL PRODUCTION OF NEW WELLS, AND BY DECLINE OF OLD AND NEW WELLS ACCORDING TO DECLINE CURVE.
B CURVE REPRESENTS TOTAL SECURED AS FOLLOWS: PRODUCTION OF WELLS PRODUCING FROM THE DEEP ZONE WAS MULTIPLIED BY THE NUMBER OF DEEP WELLS; TO THIS PRODUCT WAS ADDED THE PRODUCTION OF THE SHALLOW WELLS, AMOUNTING TO ABOUT 10000 BARRELS PER DAY.
D CURVES REPRESENT THE ACTUAL DECLINE OF PRODUCTION EXISTING AT THE BEGINNING OF THE CURVE.

FIG. 4

The expected production of the field under method B will decline as indicated in Table IV.

As this field is so nearly drilled up, and the character of the production that will be secured is so uncertain, no attempt has been

made to draw a curve under method C. There are about 120 drilling wells in the field. Many of those are marginal wells in areas where small production and water troubles are to be expected. The few deep wells which are drilling will have such small new production that no credit has been allowed.

The final curve for Huntington Beach should therefore be very much like the decline of old production existing at the beginning of any calendar month, were it not for the fact that since March there has been shut-in production at Huntington Beach. In the

TABLE IV

ESTIMATES OF DAILY PRODUCTION OF THE HUNTINGTON BEACH FIELD, IN BARRELS

Months	Method B	Modified
September, 1923	92,000	94,000
October	71,000	75,000
November	56,000	63,000
December	46,000	58,000
January, 1924	36,000	54,000
February	.....	52,000
March	.....	49,000
April	.....	46,000
May	.....	44,000
June	.....	42,000
July	.....	38,000
August	.....	35,000
September	.....	33,000
October	.....	29,000
November	.....	27,000
December	.....	25,000

future it is expected that all of this shut-in production will be released. The total production of the field will therefore decline even more rapidly than the old production, existing at the first of each calendar month since April, has declined in the past. Water troubles have already had their effect upon the Huntington Beach field so that the final curve has not been reduced from the estimates to take this into consideration. The situation at Huntington Beach is only a forerunner of that which will occur at Santa Fe Springs and Signal Hill. As the field was smaller, the effect of water and loss of gas has been less marked than it will be in the other two fields. Taking into consideration the elements bearing on Huntington

Beach, the daily average production of the field has been estimated as indicated in Table IV.

The results of this analysis may be assembled and included in a single table of estimated production of California which is submitted for the year 1924. This shows a steady decline from 734,500 barrels in January to 373,600 barrels in December. (See Table V.)

The remaining element now to be considered is the question of consumption. During 1920 the oil consumption of California rose from about 300,000 barrels to 335,000 barrels per day. During 1921 the consumption declined from 335,000 barrels to about 245,000 barrels at the time of the strike in October, but the year ended with daily consumption of 270,000 barrels. An increase of consumption from 270,000 barrels to nearly 450,000 barrels occurred in 1922. During 1923 consumption has remained below 450,000 barrels, but well above 400,000, with a tendency to increase regularly. Consumption in August was 550,000 barrels, due to summer conditions. Many small refineries in southern California placed all of their production on the market without attempting to store any of it.

The consumption of oil during the next year will depend, generally, upon conditions in the west. California oil is used extensively in Arizona and Nevada in the copper industry. Railroads in the western states which considered giving up the use of fuel oil during the shortage a few years ago are now using it more extensively. Shipping on the Pacific is increasing. The many vessels built by the government during the war burn fuel oil. The number of automobiles has increased. It seems fair to assume that all industries using oil are on a substantial basis and are being enlarged.

Neglecting the sharp increase of consumption in August, 1923, and assuming a very gradual change, it appears that consumption will increase regularly from 440,000 barrels in September to 450,000 barrels for July, 1924. At that time, and at that amount, consumption will equal production. There will be no more oil for storage and no more oil for shipment through the Panama Canal without drawing on the oil that will have been placed in storage up to that time. Thereafter consumption should continue at about 450,000 barrels per day, while production should decline regularly.

TABLE V

ESTIMATED DAILY PRODUCTION OF CALIFORNIA FOR THE YEAR 1924, IN BARRELS

Field	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Kern River	19,800	19,800	19,800	19,700	19,600	19,600	19,600	19,500	19,400	19,400	19,300	19,200
McKittrick	6,000	6,000	6,000	5,900	5,900	5,900	5,800	5,800	5,800	5,700	5,700	5,700
Midway-Sunset	81,000	80,700	80,300	80,000	79,700	79,301	79,000	79,600	78,300	78,000	77,600	77,300
Elk Hills	21,000	20,500	20,000	19,500	19,000	18,500	20,000	21,000	23,000	24,000	26,000	28,000
Lost Hills-Belridge	4,800	4,600	4,500	4,400	4,200	4,100	3,900	3,800	3,700	3,600	3,400	3,300
Coalinga	30,000	29,700	29,400	29,200	28,900	28,700	28,400	28,100	27,900	27,600	27,300	27,100
Santa Maria	12,600	12,500	12,500	12,400	12,300	12,200	12,100	12,100	12,000	11,900	11,800	11,700
Summerland	150	150	150	150	150	150	150	150	150	150	150	150
Watsonville	50	50	50	50	50	50	50	50	50	50	50	50
Wheeler Ridge	300	300	300	300	300	300	300	300	300	400	400	400
Newhall-Ventura Counties	11,300	11,500	11,700	11,800	12,000	12,200	12,300	12,500	12,700	12,800	13,000	13,200
Salt Lake	2,400	2,300	2,300	2,300	2,300	2,300	2,200	2,200	2,200	2,200	2,200	2,100
Los Angeles	600	600	600	600	600	600	600	600	600	600	600	600
Montebello-Whittier	15,700	15,400	15,100	14,900	14,700	14,400	14,200	13,900	13,600	13,300	12,100	12,800
Coyote	18,100	17,900	17,900	17,700	17,600	17,500	17,400	17,300	17,200	17,100	17,100	17,000
Fullerton	11,700	11,500	11,400	11,300	11,200	11,100	10,900	10,700	10,600	10,400	10,300	10,100
Richfield	15,000	14,700	14,400	14,100	13,800	13,500	13,200	12,900	12,600	12,300	12,000	11,900
Huntington Beach	54,000	52,000	49,000	46,000	44,000	42,000	38,000	35,000	33,000	29,000	27,000	25,000
Signal Hill	205,000	171,500	128,000	101,000	84,000	75,000	64,000	56,000	48,500	42,500	36,000	31,000
Santa Fe Springs	216,000	184,000	154,000	130,000	113,000	102,000	92,000	82,000	72,000	62,000	52,000	42,000
Torrance-Redondo	8,000	9,800	11,300	12,500	14,300	15,800	17,300	18,000	20,300	21,800	23,300	25,000
Compton	1,000	1,000	1,000	3,000	3,000	2,500	2,500	4,000	4,000	6,000	8,000	10,000
Total	734,500	666,500	589,700	536,800	500,600	477,701	453,900	435,500	417,900	400,800	385,300	373,600

While it appears probable that early in 1924 production will fall below consumption (Fig. 5), it is highly probable that the development of the new fields at Torrance, Compton, and Wheeler Ridge will be speeded up during the spring and summer, in order to take care of the deficiency. Should this be done the estimates herewith will not be realized. The outlook for the future is definite enough, however.

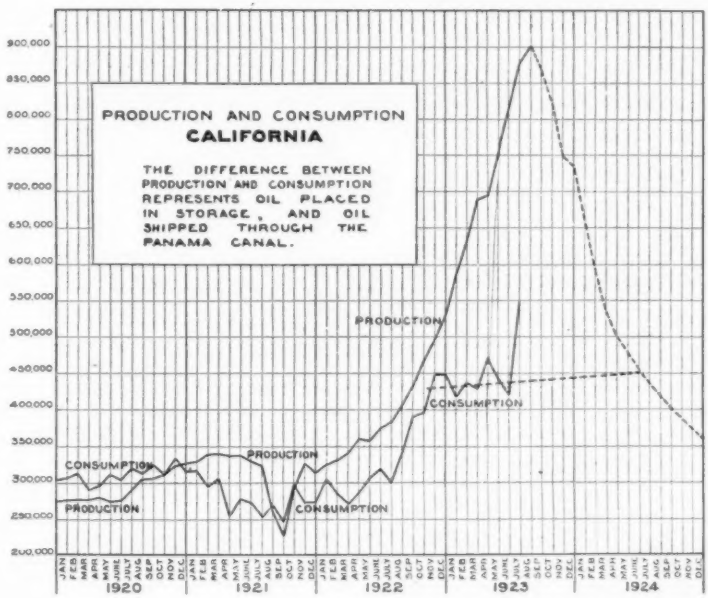

FIG. 5

The end of overproduction in California will come within the next year, and the heavy load now being carried by the oil industry will be reduced in another six months. The public generally perhaps does not appreciate that those organizations exerting themselves to store and retain oil in California are performing a genuine public service for our state, since that oil will be needed before the close of 1924.

DISCUSSION

CARL H. BEAL: With so many wells and areas of different possibilities contributing to the oil supply from southern California, I seriously doubt if our peak of production will be as sharp and distinct as many seem to think. It is more likely that the final curve showing monthly output from August to December will be serrated with various sharp peaks but with a gentle slightly downward trend during the next few months. I believe our production by the first of January will have fallen off approximately 100,000 barrels per day.

I see no probability of repetition of our 1923 output during 1924, and I think the probabilities are very strong indeed that 1924 will see a gradual decline from the beginning to the end of the year and the advent of spring should see optimism in the oil industry.

It is almost inconceivable, however, that the decline given by Mr. Jensen is a true picture of what will happen to the production of our three major pools in the Los Angeles basin during the year 1924. Such a rapid fall-off is hardly probable in view of the number of new locations to be drilled and the thickness of the sands in these three fields.

There probably are several other fields yet to be discovered in California, not only in the Los Angeles basin but also in other parts of the state. Many new companies have been organized and have profited by these three rich fields in the Los Angeles basin. They will, in all probability, spend a part of their profits in search of new deposits, thus increasing the number of wildcat wells over the number that were drilling two or three years ago. In the prospective areas of California where the geology is masked by superficial deposits, promiscuous wildcatting is almost certain to open up new pools.

WALTER STALDER: Other than the possible sources of increased production that you mention, have you made any allowance for additional territory that may be brought in by one or more of the several score of wildcat wells now drilling in California? This question is being asked because of other predictions made during the late war. At that time a committee investigated the industry and stated that according to the best informed geologists, all of the oil fields of California had been found and that outside of drilling the Naval reserves or more intensively drilling up already producing properties, there was but little prospect for increased production.[1] Subsequent developments have only too clearly shown that wildcat wells can cause a very serious situation in the industry. With this past history in mind, I can assure you that I am skeptical of predictions that do not make due allowance for all such wildcat wells.

[1] Report of the Committee on Petroleum, California State Council of Defense, July 7, 1917.

RÉSUMÉ OF THE GEOLOGY OF THE GULF COASTAL PLAIN

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The area to be considered extends from Florida westward and southward to the Rio Grande, and thence southward and southeastward to the Yucatan Peninsula in Mexico. In this belt of low elevation, rimming the Gulf of Mexico, are exposed some strata of the Comanchean, and all the strata of the Upper Cretaceous and younger formations which border the Gulf of Mexico. At its widest point, from southern Illinois to the Gulf, this belt has a width of approximately six hundred miles and narrows to a width of a very few miles, where the Sierra Madre of Mexico extends eastward almost to the Gulf, at a point some two hundred miles south of Tampico. The average width of the belt is approximately two hundred miles.

STRATIGRAPHY

As already mentioned, this entire Coastal Plain includes strata from Comanchean to recent age. The Comanchean or Lower Cretaceous is exposed along the inland rim of the Coastal Plain in Georgia and Alabama, but in approximately the center of the latter state, it is overlapped and concealed by Upper Cretaceous and more recent formations. It reappears at the southern edge of the Ozark Mountains in Arkansas, south of Hot Springs, and from this point westward and southward the uninterrupted Comanchean outcrop covers great areas in Texas and composes most of the Sierra Madre of the east of Mexico.

The Comanchean at its outcrop in Georgia and Alabama is composed almost entirely of non-marine clays and sands derived from the crystalline Piedmont area of pre-Paleozoic age. At a point in southwestern Alabama approximately 100 miles south of a line connecting the Comanchean in Alabama and the Comanchean in Arkansas, red sands and shales have been penetrated, occupying

the stratigraphic position where Comanchean strata would be expected, thus indicating the non-marine character of the Comanchean for at least a very considerable distance from its outcrop. In Florida, however, limestones probably of Comanchean age have been penetrated in several wells. The crystalline Piedmont area, with its rapid run-off and preponderance of quartzitic rocks and schists, probably accounts for the red shales and sands that predominate where the Comanchean has been penetrated in several wells drilled in Georgia and Alabama.

Westward, in southwest Arkansas, the Comanchean at its outcrop is represented by sandstones, shales, and impure limestones. South of the outcrop, wells which have been drilled have found an increasing percentage of limestones. In De Soto Parish, Louisiana, the section as far as it has been penetrated is very largely limestone. Westward, southwestward, and southward into Mexico, the limestones of the Comanchean increase in percentage and thickness until, in the Sierra Madre of Mexico, there is a thickness approximating 10,000 feet of limestone, including a part of those limestones which are generally called Tamasopa. Shales and sands are most abundant in the Comanchean in Arkansas and southeastern Oklahoma, and particularly in the non-marine beds east of the Mississippi River.

The Upper Cretaceous formations, or Gulf series, are exposed practically throughout the length of the Gulf Coastal Plain, for they are entirely overlapped, so far as known, only in central and northeastern Arkansas and southeastern Missouri. East of the Mississippi River the series is composed primarily of chalk and marl. Marl, as here used, is material composed of sands of various kinds, shales, lime, and, generally, fossils. These materials are contained in the Selma chalk and Ripley marl, which are in part contemporaneous in age. Also, it might be mentioned at this point that the Ripley marl of Alabama, although in part equivalent in age to the Taylor marl of Texas, is entirely different in character. The description of the Ripley marl has been given above, while the Taylor marl is composed primarily of calcareous clay, less correctly called shale. Underlying the Ripley-Selma group, is the Eutaw formation, composed of littoral sands and clays. Southward from the surface

terrain of the Gulf series of Alabama, wells have penetrated materials practically identical with those exposed on the surface. No shales containing a considerable amount of organic matter were noted.

West of the Mississippi River as far as the Rio Grande, the Gulf series is composed primarily of dark colored shales, two or three limestone members, and three formations in which sands are present, one being in the upper part of the Cretaceous, equivalent in age to the Navarro formation of Texas, or the Nacatoch of Louisiana; another, the Blossom, which, east of Dallas, occupies the approximate position of the lower portion of the Austin chalk or the upper part of the Eagle Ford; third, the sands of the Woodbine and Bingen, at the base of the Cretaceous in East Texas and Louisiana. At this point it might be stated that the terms "Blossom" and "Woodbine," as used in Arkansas and Louisiana, are very indefinite and the formations deserve serious study in order that accurate differentiation might be made and correct nomenclature used.

In central Texas, sands of lesser note are found in the Taylor formation, while in southwest Texas and southward into northern Tamaulipas, no sand is found with the exception of one in the uppermost formation, known as the Webberville, Escondido, or Esperanza. Likewise, south of that part of Mexico immediately west of Laredo, no sands are found in the Gulf series, except a few sandstone beds in the extreme upper portion of the series. These sandstones are best displayed in what is called the Forlon syncline, or that great synclinorium lying between the Sierra Madre on the west and the Rio Grande–Gulf system of mountains on the east. Therefore, throughout this portion of Mexico, we might expect no oil production from sand. On the contrary in this part of the Gulf Coastal Plain, the Gulf series is composed entirely of limestones and dark shales which are: the Papagallos, named by Dumble, including a maximum of 2,500 feet of dark shales; the San Felipe, of Belt and Jeffery, including some 800 feet of alternating limestones and shales; and the Victoria limestone, so named from excellent exposures in the mountains to the west of Victoria, the capital of the state of Tamaulipas, Mexico. The Victoria is generally called Tamasopa,

but is in reality a formation of rather thin-bedded, cherty, black to white limestones, having a total thickness of 3,000 to 5,000 feet and lying apparently unconformably upon what is called the Taninul limestone of the Tamasopa group. The Taninul is the producing horizon of the Lower fields and is of Comanchean age, while the production of the Panuco field is from the basal San Felipe and upper Victoria limestones of the Gulf series.

The Victoria is classified as belonging to the Gulf series on the basis of continuous sedimentation from the base of this formation through the San Felipe and Papagallos, while there is an unconformity of unknown extent between the Taninul and the Victoria limestones. The Victoria and San Felipe, according to our present understanding, are equivalent to the Eagle Ford and Austin of Texas and to the older formations of the Gulf series to and including the Brownstown marl of Arkansas, and possibly a part of the Annona chalk.

In accordance with the generally accepted theories regarding the origin of petroleum, there are abundant materials in the rocks of the Gulf series in the area extending from the Mississippi River into Mexico from which oil in commercial quantities might have been derived. East of the Mississippi, no such materials are known at the present time, though there are portions of this area where they may be present.

Gulfward from the outcrop of the Cretaceous strata, and resting unconformably upon them, are Tertiary beds. These strata are non-productive throughout the Gulf Coastal region, with the exception of the fields near Laredo, Texas, and a few isolated areas of inconsequential production, and therefore are important only because they cover the surface of most of the area where the Gulf and Comanchean series are productive and their thicknesses and the manner in which they manifest structure must be considered in order to learn the depth at which the producing horizons of the Cretaceous may be penetrated, and the probable nature of the structure in the producing horizons. The Gulf Coast salt domes, of course, are in Tertiary beds, but may be considered as a thing apart.

STRUCTURE

With the exception of the subsidence causing the Tabasco Embayment of southern Mexico, no movements of considerable extent have taken place since the deposition of the Oligocene. Since the principal structure-forming movements took place previous to the deposition of this series, for structural determinations we might consider only the Oligocene and earlier strata to be of importance, while the great majority of the work will be confined to areas of Eocene deposition.

The thickness of the strata as a factor affecting possibilities of commercial oil will likewise be confined in most cases to these areas. The thickness of the Tertiary beds is controlled by the relative position of any given area with respect to lesser structural features along the Gulf Coastal Plain. As an example, in the embayment areas, the Eocene series reaches in one case a thickness approximating 12,000 feet, while between the embayment areas this thickness is as little as 1,500 feet.

Another point which requires very serious contemplation is the relationship between the structural features of the surface Tertiary rocks and the subsurface Cretaceous beds. Due to the great unconformity, or period of erosion and folding, between the Cretaceous and the Tertiary, structures in the two systems by no means conform in all, or possibly most, instances. As a matter of fact, one might be safe in saying that in very few cases are the surface Tertiary structures conformable to the subsurface Cretaceous structures, since surface anticlines might readily overlie subsurface synclines, because of the different periods of folding. Also, movements which would have affected the inclination and direction of inclination of Tertiary beds would not necessarily have affected the Cretaceous strata, particularly where these latter formations are present at considerable depths, or where the subsurface Cretaceous materials are composed primarily of massive limestones which would require much greater forces to flex them than the slight movements which might readily affect the weaker Tertiary beds on and near the surface.

East of the Mississippi River, despite the unconformable relations between the strata, the Cretaceous structure seems to coincide with the Tertiary structure. West of the Mississippi, in Louisiana and Arkansas, the exact relation is at this moment indeterminate, but it is safe to say, in the writer's belief, that, while the structural features of the Tertiary do not present an equivalent structural relief, there is a general parallelism of features. The same might be said of those portions of Texas where wells pass from Tertiary into Cretaceous rocks. In Tamaulipas, there has been insufficient drilling to determine the exact conditions. However, surface work has disclosed in some instances a parallelism of feature, but with much steeper folding in the Cretaceous and an angular unconformity between it and the overlying Tertiaries.

In northern Vera Cruz, surrounding the producing fields, there is little or no parallelism between structural features of the Cretaceous and the Comanchean on the one hand, and the Tertiary on the other. As an example, over the Lower fields fold south of Tampico, the Upper Eocene and Oligocene show comparatively slight structural relief, and that not in conformity with the subsurface Comanchean and Cretaceous, while the producing limestone shows a comparatively steep dip to the east and a great fault or a dip exceeding 45° on the west side of the fold.

The unconformity between the Comanchean Tamasopa limestone and the Upper Eocene Alazan formation involves a thickness of strata of possibly 9,500 feet. This is the most pronounced condition of this kind in the entire Gulf Coastal Plain so far as known, though there are other similar but less important unconformities in this area.

From these few examples, we can readily see the extreme difficulty of accurate surface determinations of subsurface structure and the hazards which must attend drilling any surface structure, or apparent structure, which might be determined. Also, particularly in East Texas, Louisiana, and Arkansas, and in fact throughout the Tertiary area west of the Mississippi River, there are many cross-bedded non-marine deposits which make difficult the accurate determination of the inclination of the beds.

East of the Mississippi River, the axes of the known folds are approximately north 30° east, and northwest. West of the Mississippi to the Rio Grande, the axes trend approximately northeast, and northwest. South of the Rio Grande in Mexico, the primary axial direction is north 25° west, with a secondary direction approximating north 65° east. There are, of course, many variations from these axial directions throughout this Coastal Plain region, but on the whole the directions given predominate.

EMBAYMENT AREAS

Broadly speaking, the Gulf Coastal Plain is a great monocline, or more broadly speaking, a great embayment area somewhat more extensive than the present Gulf of Mexico. This major feature is interrupted by a number of embayments of varying sizes as well as comparatively minor folds and synclines.

The first embayment west of Georgia, where the shore line swings westward from the north-trending Atlantic Coastal Plain, is the Mississippi Embayment, and farther west, but more or less directly connected with it, the East Texas Embayment. These two together cover the most of Mississippi and Arkansas, small portions of Tennessee, Kentucky, Illinois, and Missouri, all of Louisiana, and that part of Texas east of an approximate north-south line through Dallas. Next, to the southwestward, is the Rio Grande Embayment which has been described by some geologists as the Tamaugrande Embayment, covering a large portion of southwest Texas, northeastern Nuevo Leon, and northern Tamaulipas. South of the Rio Grande Embayment lies the Tampico Embayment, covering northern Vera Cruz and extending northwestward into western Tamaulipas. Next, to the south, is the Tabasco Embayment, including the southern part of the state of Vera Cruz, all of Tabasco, and a portion of Campeche.

Petroleum has been found in all of these embayment areas, while no commercial production has been encountered outside of them, with the exception of some areas to the southeast and south of the Balcones fault zone in Texas. This does not mean that production will not be encountered between these embayment areas, but at

least it has not been found up to the present time. It is logical to suppose, however, that in these embayments, conditions of sedimentation were most favorable for the accumulation of sediments rich in organic matter.

East of the Mississippi River, conditions of sedimentation favorable to the occurrence of oil have not been found up to the present time. West of the Mississippi River and in northeastern Mexico, favorable conditions prevailed, as has been proved by the present producing areas.

A COMPARATIVE STUDY OF THE SAN JOAQUIN VALLEY OIL FIELDS[1]

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Associated Oil Company, Fellows, California

For twenty years the state of California has supplied the markets of the world with a volume of petroleum that has ranked it among the first producing areas of the world. During this time the state has yielded over 1,500,000,000 barrels of oil.

The large closing down at this time of some of its producing units, the opening of new ones and the vast increase in the volume of its production, attracts the attention of geologists with new interest to the west coast sediments of the United States and particularly to the Tertiary of California from which this vast volume of oil is obtained.

The Tertiary sediments of the west coast have an aggregate maximum thickness of over 60,000 feet largely of marine origin, for the most part laid down in waters paralleling in general the present Coast ranges. The number and position of the depressions into which the sediments were poured varied in different periods. Since the depressions were at times more or less connected, at others widely separated, and since they differed in degree of submergence, in nearness to adjacent land bodies of varying elevation and in temperature of waters, the sediments present to the geologist many very interesting and difficult problems in stratigraphy, lithology, and faunal relations. The problems are further complicated by extensive folding of varying intensity, by considerable faulting and by certain intrusives. The accompanying geologic section of the west coast sediments, from the basal complex of the Sierra westward to the sea, presents at a glance some of the difficulties to be met with in any wide correlation of strata.

The production of petroleum in California is from two general areas: one from the westward slope of the coast ranges and known

[1] Read before the Association at the Los Angeles meeting, September, 1923. Manuscript received by the Editor, October, 1923.

under the general term of the coast fields, the other from marginal structures around the southern half of the San Joaquin Valley and known as the San Joaquin Valley fields. The San Joaquin Valley occupies the southern half of the great structural depression of central California which is drained at the present time through the Golden Gate by Sacramento and San Joaquin rivers. The accompanying relief map of a portion of California (Fig. 1) shows the position of the producing areas. The oil territory of the San Joaquin Valley comprises six producing fields of the first order: Coalinga, Lost Hills, McKittrick, Midway-Sunset, Elk Hills, and Kern River. Adjacent to these are numerous producing areas of minor importance. These fields have yielded a total production of over 1,125,000,000 barrels (July 1, 1923) or 65 per cent of the total production of California. The development of the fields has been almost entirely within the last twenty-five years. For the year 1897 there is a reported production from Coalinga (only) of 70,140 barrels.

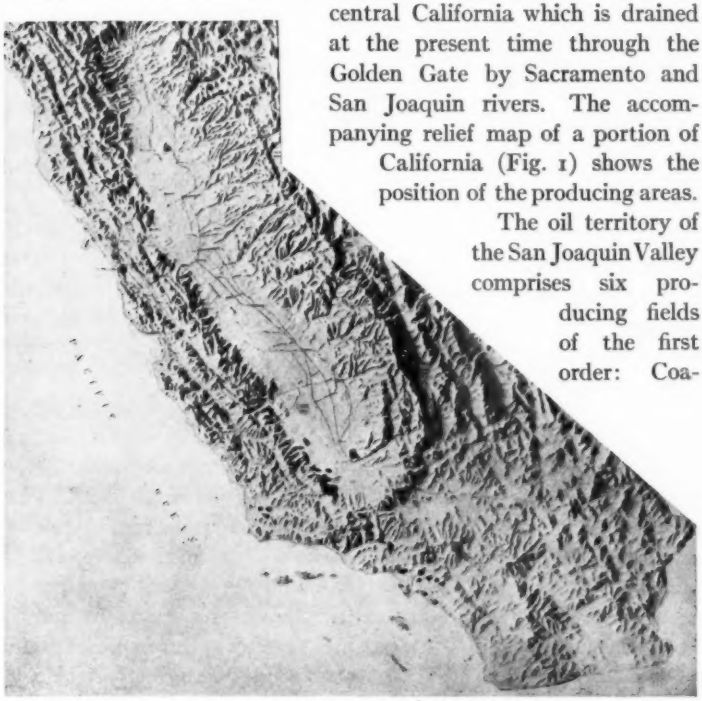


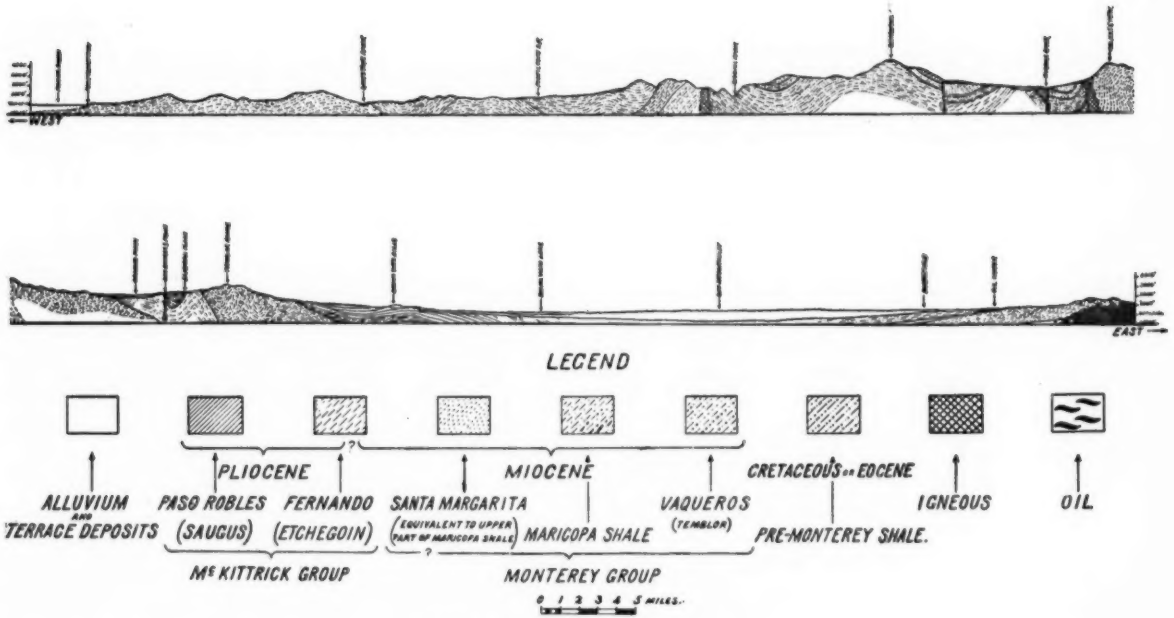
FIG. 1

The sedimentary strata of the San Joaquin Valley fields along the west and southwest sides of the valley were laid down on a metamorphosed and intruded complex believed to be of Mesozoic (probably Jurassic), age. On the east and southeast sides of the valley they rest on a basal complex of gneisses, schists, and granites. The topographic closure of the south end of the valley, connecting the west end of the Tehachapi Range with the Coast ranges culminated in Pliocene time. These strata, with the Cretaceous as the oldest of the series, are successively exposed as the present floor of the valley is approached from the west, and present on the whole a fairly complete series and record of the time (Fig. 2). Due to changes in topographic relief during the period of deposition and to oscillations in the floor of the valley and accompanying intervals of erosion, no single formation is continuously exposed around the valley nor is the lithology uniform laterally over considerable distances. The producing structures of the valley fields vary greatly in type but are all located on the lower portion of the valley's rim.

The origin of the oil is generally believed to be in organic shales, which in places attain great thickness and are found at several horizons, chiefly in the Oligocene and Miocene. The production of oil in a few instances is from the organic shale itself, but is chiefly from overlying porous strata that have served as trapping reservoirs. To show the different zones of production of the various fields and bring out more clearly the change in lithology around the valley margin, six columnar sections have been prepared (Fig. 3).[1] They are of the following areas: Coalinga, Belridge–Lost Hills, McKittrick, Midway–Elk Hills–Sunset, San Emidio–Wheeler Ridge, and Kern River. In these columns an attempt has been made to draw the formation blocks to scale, giving the maximum thickness (known or estimated) in the vicinity of production. The unconformity at the base of the Etchigoin and top of the Santa Margarita, representing the hiatus between the Miocene and Pliocene, is taken as a base line of reference because of its geological importance and its general relationship to the production of oil.

The oil of the valley fields has accumulated in various types of structure which may be described briefly in turn. The Coalinga

[1] In collaboration with Mr. E. G. Gaylord.



GEOLOGICAL SECTION

FROM

POINT CONCEPTION TO BAKERSFIELD

CALIFORNIA

FIG. 2

field consists structurally of two parts, commonly called the East Side and West Side fields. At no place in the field is there a closed fold. In the east side the oil has accumulated on both flanks of

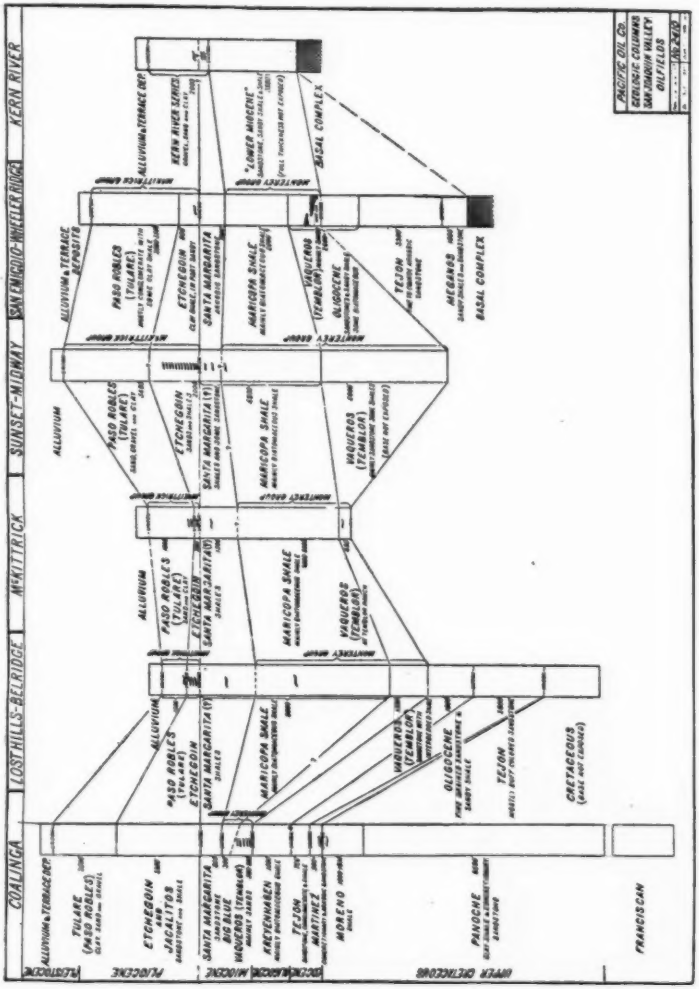


FIG. 3

the asymmetric Coalinga anticline which plunges to the southeast. The anticline is open toward the northwest, the oil-producing formation outcropping between the main producing area and the Oil City area. Separating the East and West Side fields is the sharply plunging Coalinga syncline from the upper end of which considerable oil has been produced. The West Side production is from a monocline in the western flank of the Coalinga syncline near its western end, the outcropping eroded edge of which is sealed by asphalt residues and, in part, by Pliocene beds. There are two producing zones in the Coalinga district: the lower yields a small volume of paraffin base oil from the Upper Cretaceous in the Oil City area; the upper, containing asphalt-base oil, is in the Miocene. In both the East and West Side fields the principal production comes from the Vaqueros sands, basal Miocene. The oil from the Miocene is believed to have entered from the underlying diatomaceous Kreyenhagen shale of Oligocene age. The features of principal interest in this column are the volume of the diatomaceous Kreyenhagen shales, some 800 feet thick, the favorable pooling structure in the overlying Vaqueros sandstone with its impervious capping of clay shale in the Big Blue formation. The column is conspicuous by the practical absence of anything resembling organic Miocene shales which are present in such volume farther south.

In the Belridge–Lost Hills producing area several pronounced changes are noted. The Kreyenhagen Oligocene shales have thinned to the point of disappearance. The Big Blue clay shales of the Coalinga field have disappeared or have been replaced by the great accumulation of organic shale commonly known as Monterey or Maricopa shale. This shale, highly diatomaceous, is generally believed to be the principal if not the entire source of the oil produced in this district. In the Lost Hills field the oil has accumulated in a comparatively long, narrow, anticlinal fold which plunges gently both toward northwest and southeast, broadening toward the southeast. The producing sands do not outcrop. The Belridge field is structurally quite similar to the Lost Hills field. Here there are two producing zones, one from the Maricopa itself (part of the North Belridge production) and the other from basal beds of the

McKittrick series (the main production of both Belridge and Lost Hills fields). Overlying the Maricopa shales are the Etchigoin, locally represented by marine and brackish water strata, and the Paso Robles (Tulare) fresh water bed which together have been mapped as the McKittrick group.

The rapid thinning of the diatomaceous Kreyenhagen shales southward from Coalinga and the non-appearance of the organic phase of the Monterey is believed by many to explain the absence of profitable production in the folds of the Kettleman and Kreyenhagen Hills. The overlying strata seem altogether suitable and have led to extensive prospecting: in one well to a depth of over 6,600 feet. Small showings of oil have been encountered and very suitable sands have been penetrated leaving as the reason for failure an apparent absence of an original source. The rapid thickening of the upper formations, however, to the south from Coalinga may not have been penetrated, warranting still further and deeper tests.

The stratigraphic column representing the McKittrick field is short, for the Franciscan, Cretaceous, Eocene, and Oligocene are missing. The Maricopa extends across the axis of the Temblor Range. A small amount of the production of the district is obtained from the Maricopa shales and some possibly from the Santa Marguerita, but the bulk of the oil is from the basal bèds of the McKittrick. The source of the oil is undoubtedly the same as that of the fields to the north and east, the Belridge–Lost Hills and the Midway–Elk Hills–Sunset, respectively, i.e., from the fine-grained diatomaceous Maricopa shales. The geologic column of the McKittrick district does not necessarily involve a discussion of the structure. Whether the drilling data and the topographic features indicate a recumbent fold in the southern part or a thrust or gravity fault or some other structural complication is still a mooted question. The accumulation of oil has been along a rather sharp fold which is faulted at least at its northwest portion. The exact character of the faulting which has occurred here has not been definitely determined but the present stratigraphy is probably of fault origin and such as to bring the Maricopa shales to a position overlying the later Paso Robles. This field, as a whole,

stands first in acreage production for the San Joaquin Valley fields, the production to date being 40,000 barrels of oil to the acre.

The Midway–Elk Hills–Sunset column is very similar to that of McKittrick and the structure and lithology is such as to indicate that the source of the oil is the same. The production is from several types of structure. Along the southwestern edge of the field the structure is generally monoclinal, interrupted by local or small anticlines. The production of the Buena Vista Hills is from an elongated dome. Between the Buena Vista Hills structure and the monocline to the southwest is a synclinal structure from which also considerable production has been obtained. The oil accumulation in the syncline is probably due to an arresting of the general southeasterly plunge of the syncline, producing benchlike structures. On the southeastern portion of the field in the so-called Maricopa Flat area production is obtained from a southeasterly plunging anticline whose axis appears to be more or less undulating. Throughout the principal part of this producing area there is no surface evidence of this anticline, the determination of the structure depending entirely on the interpretation of well logs. Development to date in the Elk Hills indicates that the structure is similar to that of the Buena Vista Hills.

The San Emidio–Wheeler Ridge column does not represent any area of large production but was prepared in consideration of the recent discovery of oil in the Wheeler Ridge anticline. The column includes the area westward from Wheeler Ridge to San Emidio Creek, at the extreme south end of San Joaquin Valley. The oil developed at Wheeler Ridge is of paraffin-asphalt base. It is a black oil but has, in the sunlight, a green bloom. The gravity is around 25° Baumé. The production is possibly from sands close to the contact of the Paso Robles and Maricopa shales. The source of the oil is not as yet clear. The geologic column shows an estimated thickness of 2,500 feet of Maricopa shale, 3,000 feet of Oligocene and 3,000 feet of Eocene. All three are more or less organic. The paraffin-asphalt character of the oil seems to indicate a source in part from below the Maricopa shales, which elsewhere produce only asphalt-base oil. It is possible that all three formations may have contributed to the storage.

The five geologic columns thus far referred to cover in a general way the geology of areas that are so closely related that they almost touch and have taken us down the west side and around the south end of the valley from Coalinga to Wheeler Ridge. The sixth column, that of the Kern River field, is so far removed from the other fields and is so different in other respects that it might be left out of this discussion or be made the subject of a separate report. The field is situated on the far eastern side of the valley about 5 miles north of the city of Bakersfield, 35 to 40 miles from the nearest production on the west side.

The column shows but three principal formation blocks: the Pliocene Kern River series, the Miocene equivalent of the Monterey shales, and at the bottom the granites of the Sierra Nevada Range. The production of oil is from the lower part of the Kern River series with a source doubtless in the Miocene. The producing sands are lenticular throughout the field. The producing area is nearly round with the measures tilted gently (about 3°) toward the southwest. The beds are generally considered of delta origin.

On the eastern side of the field the outcropping oil measures are crossed by Kern River. The water associated with the oil in the other fields of the valley is salt. It is significant that the water made in large volume by many of the Kern River wells is fresh and that the Kern River is flowing in its bed of sand across these unconsolidated measures. The oil produced in the Kern River field is a heavy asphalt-base oil running in gravity from 10° to 16° Baumé. This field alone has produced close to a quarter billion barrels of oil and is one of the great producing fields of the state. Due to the great thickness of the producing formation—in the center of the field over 600 feet—it will doubtless remain a producer for many years.

In closing, attention should be called to certain interesting structural and production features of general application. The producing structures of the valley fields are of two main types, monoclines and folds. In numerous instances as in the West Side Coalinga, McKittrick, and Sunset fields, the eroded edges of the monoclines are capped by asphalts and the sands near their eroded edges are filled with maltha residues effectively sealing the reservoirs. The

production from these monoclines is commonly low in gravity with the gravity increasing with depth down the dip: the lower gravity oil being due to the escape of part of the lighter components. In the anticlinal folds, particularly the domal structures, just the reverse of this is commonly found to exist. Here the highest measures of a producing zone are not infrequently a gas zone (and in some instances a dry gas) with a high gravity oil in close association both laterally and vertically with the lowest gravity oil farthest down the limbs of the structure and in the lower portion of the measures. This is particularly true of both the Buena Vista and Elk Hills, which are typical domal structures. An apparent exception to this may be recalled in the production of the Lost Hills anticline. The production of the upper measures (produced from 800 to 1,200 feet) is a 15-gravity oil. A deeper production from around 1,500 feet as in the California State lease, section 5, 27–21, varies in gravity from 31° to 34° Baumé. The explanation is probably not that this higher gravity oil may be from another horizon (the source of the light and heavier oil is doubtless the same), but that in the shallower production through the unconsolidated measures the lighter fractions have escaped, the oil being further affected by surface waters. This suggests that the upper production is a residual oil and the higher gravity oil is the original form. There are doubtless other exceptions in individual well production and in small isolated areas. The conditions prevailing in these are often difficult to explain but may not invalidate the principle applying to structures as a whole. The differences in gravity of adjacent wells producing from the same horizon and from different horizons in the same well are frequently found to be due to differences in the texture of the strata in which the different gravity oils have accumulated.

Chemical analyses of oil from various fields are not now available but from general understanding the oil of purest paraffin base is a small production from the Cretaceous in the Coalinga field. Oil of paraffin-asphalt base is produced in the Devil's Den area and at Wheeler Ridge. The oil in the other fields of the valley may carry small fractions of paraffin but are known as distinctively asphalt-base oil.

The production of the San Joaquin Valley fields reached its maximum in 1919 when over 80,000,000 barrels of crude oil were produced. The production for 1922 was about 62,500,000 and from present indications the production for 1923 will fall below 55,000,000 barrels. These figures, however, have very little bearing on the curve of decline of the valley fields. Due to overproduction in the southern fields there is a shut-in production in the Midway–Elk Hills–Sunset area alone of 45,000 barrels a day. The overproduction of oil and reduction in price have slowed down development and the tendency among producers has been to reduce operating expenses to a minimum with a result that many wells are not kept in first-class producing condition.

With the recovery of the market, the San Joaquin Valley fields will recover much of the apparent decline. Undeveloped areas of proven production, the use of the core drill in solving some of the water and oil-production problems, the steadily improving methods of recovery and collection are easily capable of placing the valley fields back into the place of first importance. Some 48.5 per cent of the proven area is yet to be developed. A conservative estimate of the future production of the San Joaquin Valley fields is 1,150,000,000 barrels. Taking into consideration the possible additions of the present proven area and prospect work, the potential position of the San Joaquin Valley fields has not seriously been disturbed.

DISCUSSION

E. G. GAYLORD: The statement by Mr. Stevens to the effect that in closed structures in the San Joaquin Valley the higher gravity oil is found in the upper portions of the measures and the lower gravity oil in the lower portion is not borne out by facts. In fact it is the exception rather than the rule.

The only structure where he can correctly say this relationship holds true is in the eastern end of the Elk Hills where at the top of the structure the oil from the lowermost sands, as at present developed, is a few degrees heavier than that from the upper producing sands. In this area it is possible that the full thickness of the productive measures has not yet been developed and whether the relationship would hold throughout the measures is yet to be determined.

In the productive area near the center of the Elk Hills structure around the Hay and Carmen leases of the Standard Oil Company the uppermost productive

sands furnish an oil around 25 degrees A.P.I. while the lower sands have produced oil of approximately 48 degrees A.P.I. It is probable that the wells which produced this high gravity oil are deeper stratigraphically than any of the wells in the first mentioned easterly area of the Elk Hills structure.

Again, in the Buena Vista Hills closed structure the deeper sands are lighter gravity than the upper sands. This is likewise the case in the Maricopa Flat area and in the Lost Hills structure mentioned by Mr. Stevens.

I believe it may therefore be stated as a general proposition that in closed structures in the San Joaquin Valley the lighter oils are found stratigraphically deeper than the heavier oils. A possible explanation of this condition might be that the upper waters, which generally speaking are sulphate waters, have reacted with the oil in the higher producing sands in some manner to change their character.

HUNTINGTON BEACH OIL FIELD, ORANGE COUNTY, CALIFORNIA[1]

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San Francisco, California

Huntington Beach oil field had produced up to July 31, 1923, about 35,370,000 barrels of oil. At present this field is classed as third in importance in potential production in southern California.

The field is located in Orange County, about 30 miles southeast of the city of Los Angeles along the southern rim of what is generally known as the Los Angeles basin. The productive area rises from the general surrounding region at 50 feet above sea-level to 126 feet, the topographic high in the field.

Exposures in the area of Huntington Beach proper are confined to cuts and gravel pits in the San Pedro formation of Pleistocene age. The San Pedro beds consist of loosely consolidated cross-bedded sands, gravels, and silts. The general surface has been smoothed over by natural weathering and by cultivation. Four miles to the southeast across the depression formed by Santa Ana River is Newport Heights, a low elevation similar topographically to Huntington Beach. Here beds of Fernando formation of Pliocene age are exposed dipping westward and southwestward at angles of from 18° to 25°. Sands and sandy shales, fairly well bedded and more consolidated than the San Pedro formation, compose the Fernando at this place. In the sea cliff immediately north of the town of Newport Beach, the Fernando is seen to lie unconformably on Puente shales of upper Miocene age. These are white or light in color, of light specific gravity, and diatomaceous, corresponding to and of the same age as the Modelo shales farther north in southern California, The contact of the Fernando and Puente extending northward is covered, but the approximate location of the contact has been determined by

[1] Read before the Association at the Los Angeles meeting September, 1923. Manuscript received by the Editor, November, 1923.

wells which reach the Puente shale without encountering the Fernando formation.

In the cliff north of Newport Beach at the contact of the Fernando and Puente shales the basal sands of the Fernando are impregnated with tar. This tar and the occurrence of inflammable gas in shallow water wells near Huntington Beach comprised the surface indications of oil. Favorable structure for accumulation was suggested by the topographic elevation which occurs at a sufficient distance from outcrops of known oil-bearing strata to allow for a complete reversal in the attitude of the beds. Surface exposures show flat-lying strata and do not reflect the underlying structure. The existence of the topographic elevation suggests only an underlying older elevation, which was an expression of structure on which there has been a tendency to build up and retain later deposits.

Prospecting was commenced by the Standard Oil Company in a well located with reference to the topography a few hundred feet northwest of Reservoir Hill, the highest elevation in the Huntington Beach area. This well was brought in in May, 1920, but because of sanding up was not completed for production until August 3, 1920. It is very close to the highest point in the structure as determined by subsequent development. The top of the oil producing formation lies at a depth of about 1,914 feet. Development to date has determined the existence of two distinct oil zones separated by intermediate water. The upper, or Bolsa, zone is 600 to 800 feet thick, and production from it is mostly from rather loose sands separated by thin layers of sandy shale. The gravity of the oil ranges from 17° to 25° Baumé. The lower zone, called the Ashton, has been penetrated in some producing wells for at least 1,750 feet. A well drilling at present has at approximately 5,550 feet an oil sand which probably represents this same zone, indicating that the zone has a thickness of possibly 2,000 feet. In contrast with the Bolsa zone, the Ashton production is from much more shaly material. The gravity of the oil from the Ashton zone varies from 24° to 28° Baumé. Between the oil zones there is a fairly persistent intermediate water sand, sometimes referred to as the

"Copeland" water, composed of 75 to 80 feet of sand and sandy shale. In areal extent as well as in thickness, the Bolsa zone is much smaller than the Ashton. (See map fig. 1.) Bedding in the two zones is probably not conformable. On the north slope where most of the development has taken place, there is a northeast dip of about 25 to 30 feet in 100 in both zones. In this direction edge conditions and production have already been reached by development. There have been so few wells drilled on the south flank of the Huntington Beach fold that no accurate location of the axis can as yet be made nor can the maximum extent of the Bolsa zone in this direction be indicated with assurance. Standard Oil Company Well No. B-2 did not encounter the Bolsa zone but has production from the Ashton. Well No. B-19, located farther to the southwest and as far toward the beach as any well yet drilled, has encountered the Ashton zone at a depth which indicates a much lower degree of dip to the southwest than has been determined for the northeast flank. Northwestward development has not been sufficient to determine the extent of oil accumulation in that direction. With a low plunge of the axis southeastward toward Newport, production has been obtained for a long distance in this direction. It seems quite possible that some oil might be encountered the entire distance across the shallow depression from Huntington Beach to Newport Beach, though with thinner oil sands and more intermediate water sands. The Mitchell well near Newport Beach is producing from the lower part of the Fernando formation where the oil has accumulated against the viscous residues at the surface in the same strata.

Initial average daily production of the discovery well in the Huntington Beach field during the first month was about 85 barrels. By January, 1921, three wells were producing and for that month they made a daily average of 328 barrels of oil per well. A year later in January, 1922, 66 wells produced at an average of 245 barrels per well per day. In January, 1923, 159 wells produced at an average of 505 barrels per well per day. For the week ending August 16, 1923, 212 wells produced at an average of 541 barrels per well per day.

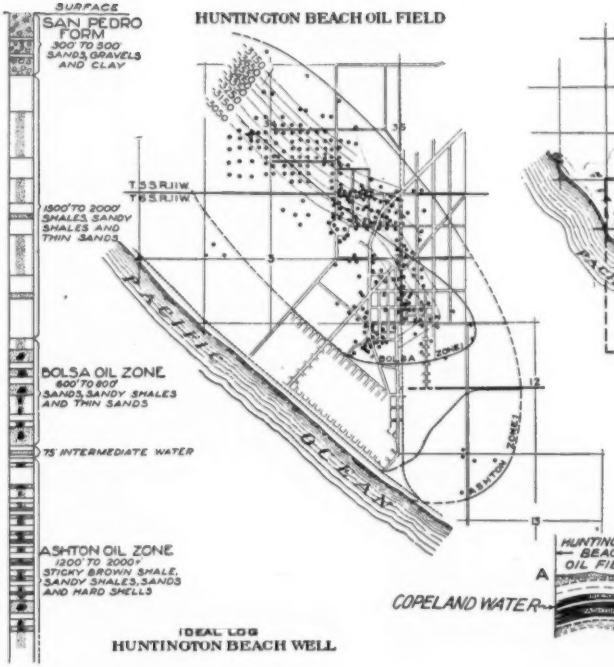
SURFACE
SAN PEDRO FORM
300' TO 500'
SANDS, GRAVELS AND CLAY
1900' TO 2000'
SHALES, SANDY SHALES AND THIN SANDS
BOLSA OIL ZONE
600' TO 800'
SANDS, SANDY SHALES AND THIN SANDS
75' INTERMEDIATE WATER
ASHTON OIL ZONE
1200' TO 2000'
STICKY BROWN SHALE, SANDY SHALES, SANDS AND HARD SHELLS
IDEAL LOG
HUNTINGTON BEACH WELL

FIG. 1

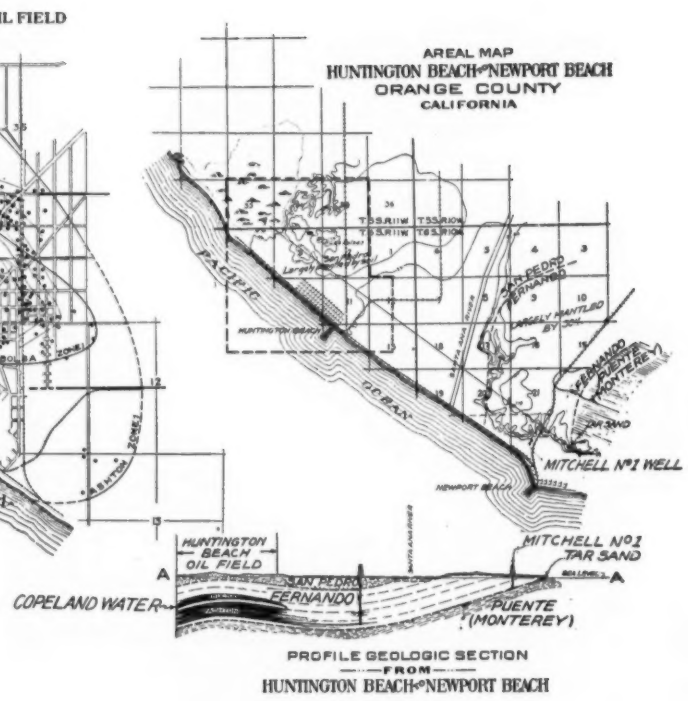
HUNTINGTON BEACH OIL FIELD
AREAL MAP
HUNTINGTON BEACH-NEWPORT BEACH
ORANGE COUNTY
CALIFORNIA
PACIFIC OCEAN
MITCHELL No. 1 WELL
TAR SAND
HUNTINGTON BEACH OIL FIELD
SAN PEDRO
FERNANDO
PUENTE (MONTEREY)
COPELAND WATER
PROFILE GEOLOGIC SECTION
FROM
HUNTINGTON BEACH-NEWPORT BEACH

FIG. 2

APPROXIMATE YEARLY PRODUCTION IN HUNTINGTON BEACH FIELD

	Barrels
1920	50,000
1921	2,561,000
1922	11,046,000
1923 to July 31, 1923	21,713,000
Total production for field to July 31, 1923	35,370,000

Commercial production from the Bolsa zone is estimated to extend over a possible area of 1,350 acres. Actual production at present is spread over an area of about 845 acres. Commercial production from the Ashton is estimated over a possible area of 4,570 acres. Actual production at present proves up about 1,520 acres. Relative productivity of the Ashton and Bolsa zones in August, 1923, was approximately 15 to 1. This, however, is largely due to the more intensive drilling for large production from the Ashton and the passing up of the shallower heavier oil. Production to August 1, 1923, from 1,520 acres, including Bolsa and Ashton zones, is 23,300 barrels per acre. It is estimated that the 4,570 acres will have an average ultimate production of 50,000 barrels per acre.

The origin of most of the oil in the Huntington Beach field is undoubtedly the Puente shales underlying the reservoir beds of the Fernando. Like all Middle Miocene shales of California, the Puente in this district is an organic shale largely made up of diatoms which could quite likely be the source for all the oil in the field. However, the lower shales of the Fernando contain considerable organic material and may contribute to the supply.

The difference in the gravity of the oil in the two zones seems explainable by the character and water content of the strata in which it is found. The lower Fernando or Ashton zone, consisting largely of shales and hard sandy shales, did not contain strata in which water was plentiful or moved freely. Therefore, the oil retained in these beds was not subjected to the chemical action of free-moving waters and is, therefore, the lighter gravity oil of the field. Sandy, porous beds predominate in the Bolsa zone, and water was probably plentiful in these strata when the oil was being

formed and forced out of the underlying rocks. That part of the oil which found its way into the Bolsa zone accumulated beneath the overlying impervious strata under conditions of direct association with water and underwent a chemical reaction which increased its gravity.

DISCUSSION

E. J. YOUNG: As has been pointed out by Mr. Gester, the Bolsa zone is separated from the lower or Ashton zone by an intermediate edge water. This so-called Copeland water was encountered early in the history of the field and caused the operators considerable trouble until its presence and position were definitely established. Effective shut-offs above the Ashton zone are obtained at depths varying from 3,100 to 3,500 feet, depending upon the well's position on the structure. The Shell Company's Ashton No. 1 was the first well to produce in this Ashton zone, and all the later wells in the northern portion of the field shut off conformably with it. The wells were drilled progressively deeper and deeper with development until there were many producing clean oil from 1,400 to 1,600 feet of open formation. The prolific production is found in the lower 600 to 800 feet of the Ashton zone, the gravity of the oil ranging from 24 to 29 degrees.

As development continued northward, a line was finally reached where edge water became a controlling factor; this was first indicated by the Petroleum Company's Brown No. 1. We are now cognizant of two edge waters in the Ashton zone which have been encroaching rapidly up the dip. The first is a water lying about 300 to 400 feet below the top of the Ashton zone and is popularly known as the "Brown" water, being first recognized with the completion of the Petroleum Company's Brown No. 1. The other edge water exists at about 1,450 to 1,500 feet below the top of the zone and has been called the "Pearce" water, having been first recognized in Amalgamated's Pearce No. 6. This water is comparatively recent and has already encroached up the dip to include such wells as Copeland Nos. 12 and 16.

These intermediate edge waters have a very important bearing upon the Huntington Beach field at the present time, and the early recognition by the operators of the seriousness of the situation has been a very great aid in the handling of this water problem.

SOME PLANETABLE METHODS

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USE OF SIGHTING POINTS OFFSET FROM PLANETABLE STATIONS

In expanding a triangulation net it is desirable to make use of sighting points already at hand and visible from considerable distances, rather than to erect flags directly over points occupied or to be occupied. Thus set-ups are preferably made near to some natural feature which may later be used as a sighting point. Such features as church and school steeples, grain elevators, lone trees, and prominent rocks are available in many localities for triangulation points. Most of such "stations" cannot be occupied conveniently, and when a planetable station is located near one of them, the writer uses the sighting point in one of the two following ways.

If the sighting point is to be used for backsight orientation, and is more than a few feet from the set-up, a "lining in" method must be used if maximum accuracy is desired. If less accuracy is required, it will only be necessary to make a large scale drawing showing the sighting point in proper relation to the point of the set-up. This diagram will be used as a guide in sighting to the left or right of the sighting point in later backsights to make use of the location previously determined close to the sighting point. The use of these two methods may be illustrated by Figure 1, which is drawn to represent a planetable sheet.

Suppose a base line a mile long is measured along a country road, and the ends of the base, *A* and *B*, are marked by small flags, each visible from the other end of the base, but not from a greater distance. Points *C*, *D*, and *E*, each a prominent natural feature visible from a distance, are located by foresight lines from the two ends of the base. It is now desired to occupy and locate a point (*h* in Fig. 1) near to a large oil tank some miles distant from *B*. The center of the tank (*H*, Figs. 1 and 2) will be used as

a sighting point. The flag at *B* will not be visible from *h*, but the point *E* may be used as a sighting point, and an accurate backsight orientation at *h* may be prepared for by a "lining in" method. While the planetable is set up and oriented at *B*, pick out a point, *F*, at a considerable distance in a suitable direction, and with the line of sight bearing on *F*, draw orientation lines near the two ends of the straight edge of alidade. Next send the rodman as near as possible to *E*, and in line between *E* and *H*.

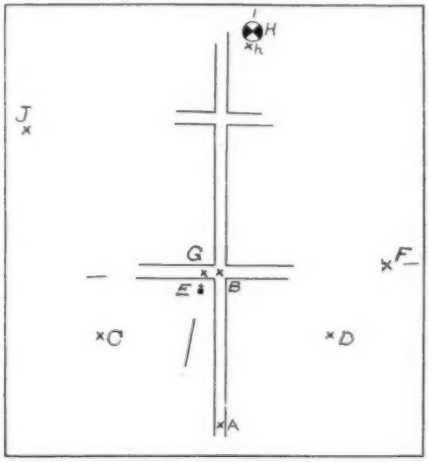

FIG. 1.—The figure represents a planetable sheet and is drawn to illustrate the use of offset sighting points.

Then proceed with the planetable in the line of *F-B* until signaled by the rodman that you are in line between *E* and *H*. It will then be easy to line in accurately on *B* and *F*, and make a set-up at *G*, which lies at the intersection of the lines *E-H* and *B-F* prolonged. Orientation at *G* is made by backsight on *F*, and a foresight line is drawn through *E* toward *H*. We may now proceed to the point *h*, which is selected to lie on *E-H*, orient by backsight on *E*, and locate by resection on *C* and *D*.

Since the point *H*, rather than the located point *h*, will be used as a sighting point in later work, make an offset diagram

showing *H* and *h* in proper relation to each other. This diagram may be put in one of the small rectangles found on the left page of most traverse notebooks. Such a diagram is shown in Figure 2. The diagram will be used as a guide in sighting to the left or right of *H* in order that the line of sight may be made to bear on *h* even though the latter point is not visible. As an illustration, suppose we occupy the point *J* (Fig. 1) and wish to locate by the three-point method, *H*, *C*, and *E* being visible. Make a preliminary location for *J*, and draw the line *Y-Z* on the offset diagram parallel to *J-H*. This may be done with sufficient accuracy by placing the notebook (or rather diagram) in approximate orientation on the planetable board, and getting the direction *J-H* by sighting toward *H* along the edge of a scale or protractor. The line *Y-Z* will show at once by inspection just what part of the tank *H* to sight toward in order for the line of sight to bear on the point *h*, which is not visible itself.

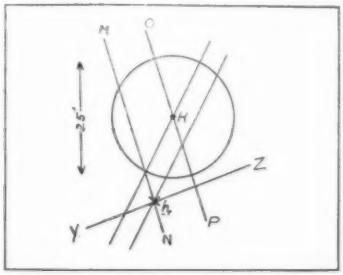

FIG. 2.—Diagram of tank and station *h* of Figure 1, to be used for determining the relation of the sighting point (tank) to the point located, for making backsights when the tank but not *h* may be seen.

A slightly different use for the offset diagrams may be illustrated as follows: Suppose that when the table has been set up at *h*, it is desired to determine the location of the point *H* instead of the point at which the table is located. Make a preliminary location for *H* (which need not be accurate), and draw the lines *M-N* and *O-P* on the offset diagram (Fig. 2) through the points *h* and *H*, both lines parallel to the line *H-D*. Scale the distance between *M-N* and *O-P*, which in the example is ten feet. Now by sighting on a point ten feet to the right of *D* (which point we may call *D'*) we may draw a line through *D* to intersect the line from *E* toward *H*. The intersection will determine the point *H*, as the line of sight *h-D'* is parallel to the line *D-H*, and may therefore be used in determining the correct direction of *D-H* on the board. The

location of the point D' must be estimated by the eye, being guided by the known dimensions of the sighting point, D. The location of H thus determined may be checked by a similarly constructed line from the point C. In making offset sights, it should be remembered that with alidades having an erecting prism the right and left of the image are reversed. Thus if we wish to sight to the right of D, it is necessary to sight on a point which through the telescope appears to be on the left of D.

PREPARATION OF CORRECTION TABLE FOR USE WITH GRADIENTER

Many of the alidades now in use by geologists are provided with a gradienter screw, which is used for reading small vertical angles. If properly used, these screws may be made to give considerably more accurate results than the vertical arc. A correction table should be used with the gradienter for maximum accuracy. The following method for preparation of such a table has been found more accurate than other commonly used methods. The table is theoretically correct only when the distances used are real distances, such as would be scaled from the planetable sheet triangulation points, and not observed stadia distance. For most angles read with a gradienter the difference between the observed stadia distance and real distance is so slight that its effect may be neglected, or by a slightly more complicated method of figuring than given in the following, the table may be made to apply to observed stadia distance.

A stadia rod is fixed in a vertical position, as against a telegraph pole. A distance from the rod of 100 feet is accurately determined with a steel tape, the table set up, and the alidade placed so that the cross axis of the alidade lies accurately above the measured point. The alidade is sighted toward the rod, the gradienter screw is set at zero, and the telescope is approximately leveled, using only the thumb screw which clamps the horizontal axis. The gradienter screw is then backed up a short distance and screwed forward until the gradienter reading is again zero. The rod is then slid up or down until the middle hair intersects an even foot mark. Now by turning the screw in until the hair inter-

sects successive foot marks on the rod, true values may be determined for each gradienter reading. Thus if the first foot mark from where the work started is reached when the gradienter records 1.03, it means that .03 should be subtracted from all gradienter readings of one full turn to obtain a true value for the angle through which the line of sight has been turned. A table may be prepared showing either true values to be used for each indicated gradienter angle or it may show the amount to be added to or subtracted from the value read to obtain the correct figure. In reading angles for use with this table the gradienter screw should be started at approximately the same place from which it was started in the preparation of the table.[1]

Before starting these operations, the surface of the lever arm at the place of impact of the gradienter screw should be smoothed. With most instruments in use at present this arm is made of material of the same hardness as the end of the screw, so that in time a pit forms at the point where the end of the screw presses. This will affect the accuracy of the readings, as the construction is such that the screw slides slightly up and down on the lever arm when turned in or out. If it works against a pitted surface, its action will not be uniform. A preferable construction would embody a smooth plate of hard metal for the end of the screw to work against. This construction is used in one instrument that has come on the market recently.

USE OF TARGET ROD FOR STADIA MEASUREMENTS

During the past season the writer has tried out with very satisfactory results the use of a target rod in place of the ordinary self-reading stadia rod. Figure 3 shows the character of the rod used. It consists of two wooden sticks one inch square and five feet long, constructed with metal heads and points so that they may be driven in the ground. On each stick is fixed a target ten inches square, painted red and white on alternate quarters. The targets may be moved up and down on the rods and clamped in any desired

[1] Another method for the construction of tables for the gradienter is given by Kirtley F. Mather in "Manipulation of the Telescopic Alidade," *Jour. Sci. Lab. Denison Univ.*, Vol. 19, pp. 133–34.

position. A sleeve is fixed on one rod through which the other rod may be slid, and the two used as an ordinary target rod for distances up to that corresponding to the stadia interval for the full extension of the rod, which is about 8.5 feet between targets. For distances greater than 1,700 feet it is necessary to use the targets for so-called "ground rod" readings. One of the rods is driven in the ground to stand upright and the other held at a distance from it in a plane normal to the line of sight from the instrument to the targets. The target held by the rodman is moved back and forth in response to signals from the instrument man until the two targets are just the stadia interval apart. The distance between the targets is then measured with a tape and signaled back to the instrument man. With this method it is of course necessary for the barrel of the alidade to be revolved on its longitudinal axis so that the stadia hairs are in a vertical position. In reading a vertical angle the hair which would normally be the vertical hair is used for the horizontal hair.

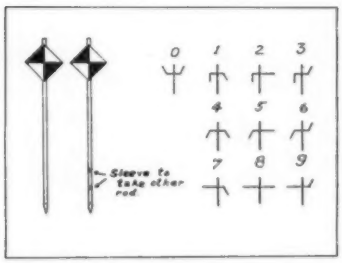

FIG. 3.—Shows target rod and simple system of arm signals for use of rodman in signaling distances to the instrument man.

The writer uses the system of arm signals for numbers shown in the diagram. In giving signals, a red flag is always held in the same hand to aid the instrument man in reading the signals. This system of signals can be learned in a couple of days so that numbers can be given or received correctly with little effort.[1]

The advantages claimed for this rod as compared to the ordinary stadia rod are as follows: (1) Much greater distances may be read. Sights of as much as two miles have been made by the writer, and even longer sights could be made by using slightly larger targets. (2) In taking sights toward the sun, the outline of the targets may

[1] Many geologists prefer to use the two-arm semaphore code developed by the army signal corps, as this makes possible not only the transmission of numbers, but also the rapid sending of verbal messages.—EDITOR.

be seen when it would be utterly impossible to read any of the markings on a rod. (3) Greater accuracy is obtained, as the cross hairs may be set more accurately on the targets than divisions on a rod can be read. (4) The rod is much lighter and more compact than an ordinary stadia rod. It is easier to carry in the field, and, by removing the targets from the rod, it may be shipped by express without trouble or may be stowed out of sight in a car in case it is desired to keep the equipment unobserved. (5) There is no chance for error on the part of the instrument man in reading the distance on the rod or in reading the foot mark on the rod to which the vertical angle was read. This is a considerable advantage when it is necessary to use an inexperienced instrument man. The rodman can keep a record of the distance to each station and later check the correctness of the figures used by the instrument man. (6) In taking ground-rod reading, both targets are about four feet above the ground and are less affected by heat waves than the lower part of a rod held close to the ground.

The following may be urged as objections to this method: (1) Distance determinations require more time than with the self-reading rod. This is true for an instrument man experienced in making rod readings, when the rod may be clearly seen. But if the instrument man has difficulty in seeing the divisions on the rod, as is often the case, or has to count the number of feet intercepted between the cross hairs, he usually uses more time than is necessary for the ground-rod method. The writer has timed himself and gets an average time of a little over three minutes for readings where the distance is less than a mile. It is believed that the advantages of the method more than compensate for the slightly greater time required. (2) The rodman should have binoculars in order to see the signals of the instrument man on long sights. This is, however, only true for sights which would be beyond the scope of the ordinary rod method. (3) An error may be introduced in the distance determination if the rodman fails to hold the two targets in a plane normal to the direction of the line of sight from the instrument.[1]

[1] The writer made tests to determine the error which may be introduced in this way, with the following results: Five men were tried out, each making ten settings of the rods, the angle of error being accurately determined for each setting. The

(4) With the ground-rod method there is no possibility of getting level sights for the determination of difference in elevation. (5) In some brushy or tree-covered areas, readings may be made possible by holding a rod high in the air above the level at which the ground rods could be easily manipulated.

DISCUSSION

K. C. HEALD: There are many regions, particularly in timbered country, where it is desirable for the instrument man to be able to get a rod reading no matter how far away the geologist may be. Commanding stations for the instrument man may be hard to find, and a single shot a mile or more in length may save hours of arduous traversing.

E. M. PRICE: I question the necessity of using two rods in establishing a horizontal base and wish to ask whether time would not be saved by bringing, say, the left stadia wire on rod, and then signaling the rodman to move to the right until subtended by the right stadia wire, using the same rod for both positions.

WALTER ENGLISH: I agree that time might be saved, but believe that two rods are conducive to better visibility and accuracy.

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maximum error in the fifty settings was 21°, which corresponds to an error in distance of 65 feet per 1,000. Two of the men made no error of more than 10°, and a third only exceeded this once by 3°. Ten degrees corresponds to an error in distance of 15 feet per 1,000, and it is believed that with proper care this error should not be exceeded. The average error for all settings was a little less than 6°, which gives an error in distance of only 6 feet per 1,000. If greater accuracy than the above results indicate is desired, a small sextant could be attached to the top of the rod held by the rodman and used in locating the rod in its proper relation to the other rod and the planetable. In this connection it must be remembered that an analogous error is made with the ordinary rod method when the rodman fails to hold the rod in an exactly vertical position.

A SECTION OF THE MONTEREY (SALINAS) SHALES IN PINE CANYON, MONTEREY COUNTY CALIFORNIA

WALTER STALDER
San Francisco, California

On the west side of the Salinas Valley in the vicinity of King City, Monterey County, California, is an area of bituminous shale. This is a part of a larger shale area which has been described previously in a general way but as yet has been neither mapped nor studied in detail. In 1917 some work was carried on by the writer during the course of which a cross-section in Pine Canyon was measured. The section is here described and the nature of some of the beds, particularly with relation to oil indications, is noted. In the work of measuring the thickness of the beds, the writer was assisted by Mr. Irving Miller.

This bituminous shale was first noted by William P. Blake in 1855. Subsequently the formation has become known to geologists and oil operators in California as the "Monterey shale formation," the "Monterey shale series," or the "Monterey shales." Elsewhere in California the shale has been found to contain interbedded sandstone members. Because of this fact A. C. Lawson for the United States Geological Survey has recently classified the shale with its interbedded sandstones and other sandstones of the Lower Miocene under the general name "Monterey group."[1] In view of this use of the term Monterey, Walter A. English has proposed the name "Salinas shale"[2] as a substitute for the beds which occur on the west side of the Salinas Valley. It might be mentioned, however, that according to common usage any sandstone member of the Monterey group is called a Monterey sandstone and likewise any shale member is a Monterey shale. All of the sandstone members of the Monterey group can be designated very properly as the Mon-

[1] *U.S. Geol. Survey, Folio 193*, p. 9.

[2] *U. S. Geol. Survey, Bull. 691*, p. 228.

terey sandstones and all of the shales may be called the Monterey shales. The simplification in nomenclature in defining the group and the change in name suggested by Mr. English is appreciated. It is generally realized by California geologists, however, that until the west coast Tertiary beds have all been mapped carefully and studied thoroughly, any classification will be subject to change.

In a large way the geology in the vicinity of Pine Canyon is simple. To the west lie the high peaks of the Santa Lucia Range, composed chiefly of a granite mass which reaches its greatest eminence in Santa Lucia Peak. Flanking the granite mass and with a general northeasterly dip toward Salinas River, are the Vaqueros sandstones and shales of Lower Miocene age, the lowest division of the Monterey group. Above and resting upon the Vaqueros sandstones are the Monterey (Salinas) shales, limestones, dolomitic shales, dolomites, tuffs and cherts of Middle Miocene age. These strata also dip in a general northeasterly direction but are involved in small folds toward the valley. The Monterey shales in this vicinity are followed by the Santa Margarita (Upper Miocene) sandstones and shales which in turn, are overlaid by sandstones, gravels, and shales of the Paso Robles, fresh-water Pliocene, formation. These younger beds also dip toward the Salinas Valley and overlap in places the Santa Margarita sandstones and the Monterey (Salinas) shales. Later terrace gravels, stream deposits, and sand dunes constitute the youngest deposits in the region. Salinas Valley in this vicinity occupies a broad syncline.

In the section measured, no sand strata whatever were found; the shales and associated fine-grained rocks are a unit, as far as seen in successive outcrop. In the actual measurement of the beds, Section *A–B* in Pine Canyon was chosen after considering the entire west side of the Salinas Valley for a distance of forty miles. The reasons for choosing this locality were that the shales and associated rocks can be followed across their outcrops in an almost straight line, the successive outcrops are nearly continuous, the observations are at fairly uniform elevation, and the extremely thick brush which covers the eastern slopes of the surrounding hills can be avoided. Measurements were discontinued at point *B* because no new unmeasured strata were observed between *B* and *C* and beyond

C, strata of the Paso Robles formation and later terrace deposits overlap the Monterey (Salinas) shales, obscuring them from view until at the point *D* where cherts come to view. The measured section *AB* reveals 4,900 feet of sediments comprising the greater part of the shale beds. Should the shales have the same ratio of thickness to the horizontal distance between points *C* and *D* as between *A* and *B*, there should be added to the 4,900 feet actually measured an additional 1,350 feet, making a total of 6,250 feet as the possible thickness of these beds in Pine Canyon. They are, therefore, recorded as having a minimum measured thickness of 4,900 feet and a possible thickness of 6,250 feet.

These Monterey (Salinas) shales and associated rocks in Pine Canyon are of the same general bituminous nature as similar rocks in other parts of California. At the base are bands of limestone, organic shale, dolomitic limestone, flinty shales, and flints, varying from one-half inch to fifteen inches in thickness. On fresh fracture the limestones have a strong petroliferous odor, and where cracked the dolomitic limestones and flinty shales are usually filled with asphalt residues. These rocks constitute the first fifty feet of the Monterey (Salinas) shale but soon give way and are subordinate to organic shales of a tough, resistant, largely dolomitic nature, in part semi-flinty, weathering on the surface to brown, yellowish, gray, and white fragments, and frequently discolored with petroleum residues where unweathered and more organic in character. The harder semi-flinty beds stand out more boldly in outcrop but search reveals softer beds of purer diatomaceous shales in contact with them. All of these beds usually occur in bands varying in thickness from a half inch to a foot or more, and where soft, thicker bands are frequently found. The tough, hard shales constitute the largest part of the measured section.

Lenses and bands of dolomitic limestone from three inches to as much as three feet in thickness are found at frequent intervals through the section. Where cracked, the seams in these bands invariably contain dry asphalt residues, but in some cases also, calcite. Thirty-five separate dolomitic bands interstratified with the shales were counted in the upper 1,200 feet of the beds measured. Near the axis of the small anticlinal fold indicated to the

right in Figure 1 the dolomitic limestones were observed to be particularly well cracked and seamed with dried and sometimes plastic asphalt residues. Three sulphur springs were found, as indicated on the cross-section.

No oil seepages were observed along the line of the measured section but on Vaqueros Creek, twelve miles to the northwest, several tar seepages occur near the base of the shales.

Beyond the measured section at *D* the best exposures of cherts observed in Pine Canyon were found in outcrop. They dip here at angles of from sixteen to twenty-three degrees eastward, and, although not folded at this particular place, certain bands have been crushed and reduced to particles varying from the size of coffee grounds to the size of a pea, while others contain still larger fragments in the cracked mass. The interstices between these particles are filled with dry petroleum residues. Examination reveals the fact that only a few of the chert bands have been thus shattered, and that others are hardly cracked at all. In view of the fact that in the Santa Maria oil field, California, many of the oil wells derive their production from similar cracked cherts and shales, the occurrence of these particular beds in Pine Canyon is of special interest.

It appears that the movement in the chert strata caused by adjustments due to tilting without anticlinal folding is sufficient to crack some of the bands and to make them porous. It is possible that they may be so cracked in some places but unbroken in others that where they form the oil measures in a commercial field the field may be distinctly "spotted." The fact that some wells in the Santa Maria oil field encountered petroliferous cracked shales and cherts while neighboring wells found no oil suggests that the conditions observed in Pine Canyon may offer an explanation which is applicable to any oil field which obtains oil from flints, cherts, hard shales, or limestones which are cracked. The nature of these cracked cherts also indicates that oil concentration in them may be of the same general type as in lens-shaped sands such as are found in places on the west side of the San Joaquin Valley, and if such is the underground condition, dome or anticlinal structures may not be necessary for the accumulation of oil in such areas.

Petroleum-stained dense shales which give no effervescence when treated with cold hydrochloric acid but do effervesce when warmed

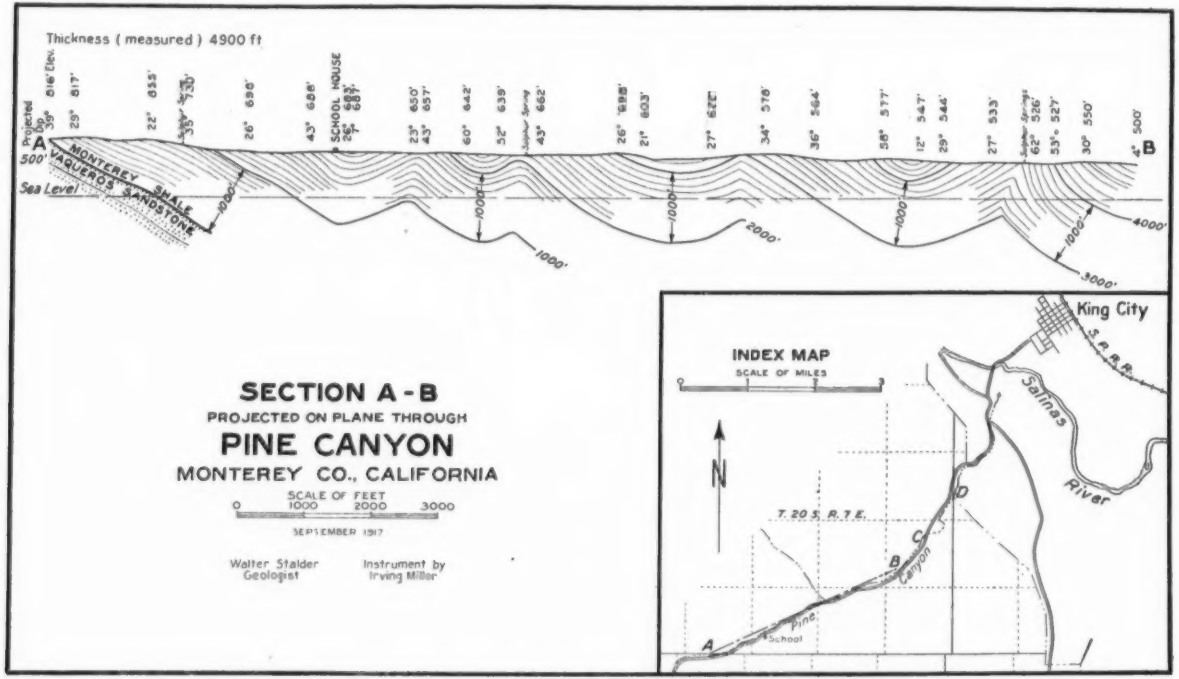
Thickness (measured) 4900 ft
Projected Dip
Elev.
A
B
500'
Sea Level
MONTEREY SHALE
VAQUEROS SANDSTONE
SCHOOL HOUSE
Sulphur Spring
1000'
2000'
3000'
4000'
SECTION A - B
PROJECTED ON PLANE THROUGH
PINE CANYON
MONTEREY CO., CALIFORNIA
SCALE OF FEET
0 1000 2000 3000
SEPTEMBER 1917
Walter Stalder
Geologist
Instrument by
Irving Miller
INDEX MAP
SCALE OF MILES
King City
S. P. R. R.
Salinas
River
N
T. 20 S. R. 7 E.
A
B
C
D
Pine
Canyon
School

FIG. 1

with the acid are dolomitic. The dolomitic character of the shales suggests the former presence of sea water, the magnesium chloride of which acted upon the calcium carbonate of the shales forming the dolomitic shales. That calcium carbonate is present in some of the heavy shales is indicated by foraminiferal remains which may be observed frequently in some of the rocks which have not been completely altered. Magnesium salts almost invariably crystallize out of water seeping from the shales.

The petroleum stains in these dolomitic shales, together with distinct evidence of petroleum in the limestones and dolomites themselves, further suggest that oil originating in the organic shales is derived from foraminifera as well as from diatoms and that it is, therefore, not necessary to have an abundance of diatomaceous shales in any region if the dolomitic or calcareous shales derived from foraminifera are present. This seemingly has an important commercial application, for investigators have been frequently inclined to reject California Tertiary areas which do not have an abundance of light, highly diatomaceous shale in the vicinity.

From what has been observed, this district with its great thickness of fine grained sediments invites a further much more detailed scientific study in relation to the origin of the oil and its occurrence under those conditions of cracked cherts, dolomitic limestones, or other brittle rocks which are here so well illustrated in outcrop as to be an index of what might be expected in many prospective oil fields where rocks of similar nature are involved.

EARLY OIL DEVELOPMENT IN CALIFORNIA[1]

W. W. ORCUTT
Los Angeles, California

California has always been a land of romance. The events of its history are like the acts of a drama. Even before its definite discovery, it so stirred the imagination of men, that in his novel, published in Madrid in 1510, Ordonez de Montalvo gave the name "California" to a mythical island in the Pacific lying "to the right of the Indies and very near the quarter of the terrestrial Paradise." Therefore, in 1542, when the hardy *conquistadores*, under Cabrillo, turned their prows to the northwest, they were searching for this prophesied El Dorado, this "Land of Heart's Desire."

Following Cabrillo, whose bones still moulder in one of our Channel Islands, came the Padres under Junipero Serra. The story of their devotion to the cause of Christ in a heathen land is written in California's noblest heritage, the Missions, which, like a string of jewels, lie along the state from San Diego to San Francisco.

The glamor of romance still lingers in the later settlement of California by the Spanish Dons, which culminated in the "Splendid Idle Forties." Then came the dramatic discovery of gold at Marshall's Mill in 1848, which so excited the cupidity of men of every nation and clime, that by ship, by oxcart, and on foot, they crowded to search for this hidden treasure.

In this connection, it is interesting to note that as early as 1833, Don Abel Stearns, a pioneer of Los Angeles County, whose name is perpetuated in the "Stearns Lease" of the Union Oil Company of California, made a discovery of gold in the hills near Newhall. The gold discovered was sent to the mint at Philadelphia where it was coined and then returned to the discoverer.

[1] Read before the Association at the Los Angeles meeting, September, 1923. Manuscript received by the Editor, December, 1923.

With the waning of the gold excitement and the exhaustion of the mines, the treasure seekers were on the lookout for other forms of wealth in this "Land of Promise."

About this time Colonel Drake had drilled his first well in Pennsylvania and found oil, "the black gold of commerce," in paying quantities. Once more the imagination of the adventurous within her borders was aroused by the hope that California should again prove the bountiful mother and be "oil-bearing" as well as "gold-bearing." There was a reason for this hope because the number and extent of the oil seepages and brea beds in Ventura and Los Angeles counties had become a matter of common knowledge.

The California Indians knew well the location and extent of the brea beds and oil seepages. Hard asphalt was used by them in mending mortars and pestles, and for cementing basket work on top of shallow mortars to increase their capacity. It was also used in fastening the arrow and spear heads to their wooden shafts and for making impervious to moisture the jars used for water and the large baskets utilized as granaries for the storage of food and seed.

When the Portola Expedition left San Diego on their march over land to San Francisco, at a point a few miles below Santa Barbara they found Indians making wooden boats, "pitching them within and without" with asphalt. This place Portola named "Carpinteria," meaning in Spanish "the carpenter's shop."

The Indians used the light oil from the seepages for coughs and colds, and for cuts and burns. This oil was highly prized, and was an article of commerce between the Coast tribes and the Indians of the interior, who were remote from the source of supply.

Likewise, the early Spanish Dons of California, the Padres and their vaqueros and Indians, knew of the existence and location of these same oil seepages and brea beds. There is a legend from the San Fernando Mission to the effect that in 1855 General Andreas Pico and his nephew, Romulo Pico, took oil for experimental and refining purposes from the seepages and hand-dug pits in the canyon near Newhall which bears their name. This is the first reference in the history of California where an attempt was made to utilize crude petroleum.

However, in the early sixties a merchant by the name of Gilbert had a small refinery in the town of Ventura in the Ojai Valley. The oil he used came from hand-dug pits and from natural seepages which abound in the vicinity of Sulphur Mountain. In the early part of 1864, Professor Silliman of Philadelphia, while traveling on the Pacific Coast, met Mr. Gilbert and was much impressed with the oil possibilities of Ventura County. Professor Silliman was so enthusiastic over the prospects that he immediately wrote a letter to Thomas Scott of Philadelphia, a man of ability and considerable means, who was then associated with the Pennsylvania Railway System. An extract from Professor Silliman's letter, referring to the Ojai Ranch, reads as follows:

> The property covers an area of 18,000 acres of land in one body, on which there are twenty natural oil wells, some of them of the very largest size, The oil is struggling to the surface at every available point and is running away down the rivers for miles. Artesian wells will be fruitful along a double line of thirteen miles, say for about twenty-five miles in linear extent. The ranch is an old Spanish grant of four leagues of land, lately confirmed and of perfect title. It has, as I stated, 18,000 acres of the finest land, watered by four rivers, and measures in a straight line, in all, nearly thirteen miles. But its great value is in its almost fabulous wealth in the best oil.

Thomas Scott soon succeeded in interesting some of his friends, and a syndicate was formed which purchased the Ojai Ranch and other properties in Ventura County. In the early part of 1865 they secured in New York City the first drilling equipment ever sent to California. This consisted of three boilers, three engines, casing and drilling tools, a refining furnace, retort, and wooden barrels in which to handle the oil. A barrel of oil in those days meant just that: a wooden container having a capacity of forty-two gallons.

Thomas Scott had two young nephews whom he sent to California to look after his interests. One of these was Thomas R. Bard, who was later so great a factor in the development of the state, and for whom the town of Bardsdale, in Ventura County, was named. Mr. Bard was for a long time President of the Union Oil Company of California, and was a large landholder. He also represented California at Washington as United States Senator.

Scott's syndicate selected a location for its first well near the tar beds, on the east bank of San Antonio Creek (Ventura River), about five miles from the town of Ventura, which well was completed in 1866 at a depth of 500 feet. Some tarry oil, which formed the brea bed, was encountered, but the well was not a success No. 2 was located five miles farther up the creek. It was drilled to 520 feet and found some oil, though in small quantities. No. 3 was drilled twenty miles from Ventura on Sisar Creek. near the outcrop of the oil measures. It was intended to drill this well to a depth of 1,500 feet, but upon the advice of Jackson and Torrey, two celebrated chemists of New York, the well was abandoned at a depth of 320 feet, as was also No. 4, located near No. 3, at a depth of 300 feet. Upon the advice of Jackson and Torrey, No. 5 was located on a big seepage in the same locality. This well was drilled with a spring pole. Between 80 and 100 feet oil was struck which filled six of the wooden barrels daily by pumping. No. 6 was drilled near by with the machinery from New York, and was the best well of all. It was 550 feet deep and produced daily from fifteen to twenty barrels of good grade oil. This well was a consistent producer for many years. The property was later named the "Silver Thread."

This development took four years' time and an expenditure of $200,000 in money, which was considered lost, because, although success had been attained in finding oil, there was only a very limited market, and it would take many years to repay, from profits, the large sum of money expended to that date.

Simultaneously with the drilling of Ojai No. 1, Leland Stanford, in furtherance of his railroad project with Huntington and Crocker, was attracted by the seepages and brea beds in Ventura County, and, miner-like, decided to drill a tunnel in the south slope of Sulphur Mountain, so located as to intercept the steep dipping oil sands outcropping at its base, which oil sands created a line of seepages some sixteen miles in length. The tunnel was completed in 1866. It was eighty feet in length, with the floor so inclined to the mouth that the oil flowed by gravity into tanks just a little lower in elevation. This tunnel showed the practicability of this method of producing oil, and for twenty-five years tunneling for

oil was carried on intermittently. In all, thirty-one tunnels were drilled into the face of Sulphur Mountain, ranging in length from 80 to 1,600 feet, with production ranging from one to twenty barrels per day of good oil.

The first oil well in Pico Canyon was drilled in 1875 with a spring pole by C. A. Mentre. This well was located on the very axis of a steeply dipping anticline, and showed two barrels of 32 gravity oil at 30 feet. This well was deepened to 75 feet, where it produced five or six barrels per day. No. 2 was also drilled with a spring pole, with about the same production; but No. 3 was a dry hole. No. 4 produced 150 barrels at a depth of 600 feet.

The showings in these three wells soon attracted attention, and in 1875 Ex-Mayor Bryant of San Francisco became interested in the field. In 1876 Messrs. Bryant and Scofield organized the California Star Oil Company, and Mr. Mentre assigned his lease to this corporation. In 1879 Mr. McPherson and C. M. Felton came into the field, and in that year organized the Pacific Coast Oil Company, which some years ago was absorbed by the Standard Oil Company of California, and became the nucleus of the Standard's holdings in California.

In 1883, Lyman Stewart and W. L. Hardison, who had already been identified with the oil industry in Pennsylvania, arrived in California and drilled four wells on Christian Hill, just east of Pico Canyon. These wells were all dry holes. A fifth well, which was a good producer, was drilled to the west of Pico Canyon. This well was sold to the Pacific Coast Oil Company for enough money to reimburse Messrs. Stewart and Hardison for their previous drilling losses on Christian Hill, and is still producing after forty years. Messrs. Stewart and Hardison then moved to Santa Paula, Ventura County, and soon after expanded their operations, which were successful, making that county the principal center of the industry. The characteristic perseverance and faith of these two oil pioneers, which led them to drill a fifth well after four failures, later laid the foundation of the Union Oil Company of California.

During the twenty years that this development of oil was taking place, some attempts were made to refine the crude oil obtained. However, it was not until 1876 that the first practical refinery

was built at Newhall by D. C. Scott and a Mr. Wood. This refinery was located near the old cemetery, one mile east of the town on the present highway. The capacity of the refinery was twenty barrels per day, and the oil was put in wooden barrels and hauled by teams from the wells. The layout of this plant can be recognized from the roads, grades, and the position of the stills as located by the remains of the old bricks.

In 1879 a new and up-to-date refinery was built by J. A. Scott and Mr. Morrison near the present Southern Pacific Railroad, one-half mile east of Newhall. This plant is still standing, and shows very clearly the arrangement and method of refining.

In 1878 E. A. Edwards built a refinery, with a daily capacity of twenty barrels, at the mouth of the Little Sespe, in Ventura County. He sold his kerosene in Los Angeles, and the lubricating oil to A. C. Dietz of San Francisco, and to Allen & White, who were connected with Leland Stanford of the Southern Pacific Railroad Company.

Thus, little by little, the oil business progressed. The records at the Port of Wilmington show that ninety-seven barrels of crude oil were exported for the year 1873. Today this harbor is the largest oil export port in the world.

During the early and middle seventies oil development in Los Angeles and Ventura counties was being prosecuted in several places. In 1876 E. A. Edwards drilled a well for Adams and Thayer in what is known as Adams Canyon in Rancho Ex-Mision de San Buenaventura. This well, which was known as Old Adams No. 1, was drilled on a large seepage which covered some 2 acres of ground. It was 80 feet deep and produced some two or three barrels of heavy oil. Later on, Adams No. 1 was drilled by D. C. Scott. It was located 100 feet south of Old Adams No. 1, and was a fairly good producer. In 1884 Hardison and Stewart drilled Adams No. 2, located about 100 feet south of Adams No. 1. No. 2 was put on the pump and drained all the oil out of Adams No. 1; and likewise Adams No. 3, drilled 100 feet south of No. 2, drained Adams No. 2, making both No. 1 and No. 2 unproductive. No. 3 was pumped for a great many years.

In 1876 the Los Angeles Oil Company was formed to develop some 800 acres of government land located in the Little Sespe

district in Ventura County. This locality abounded in oil seepages, but was exceedingly rough and inaccessible. Expensive roads were built, and finally in 1877 the first oil well was completed in this district. Mr. Edwards' refinery, located at the mouth of the Sespe, was completed in 1878, and drew its source of refining crude from this well.

The first pipe line for transporting oil was laid in 1879 from the Pico field to the second refinery built near Newhall on the Southern Pacific Railroad. The pipe line was 2 inches in diameter and 5 miles in length. The oil flowed by gravity.

In 1884 and 1885 pipe lines were built from the Little Sespe wells, from the Silver Thread wells, and from Adams Canyon into Santa Paula. C. A. Burrows laid the first oil pipe line on the Pacific Coast, carrying oil to tidewater. The line was 4 inches in diameter and 16 miles in length, extending from Santa Paula to the town of San Buenaventura. The oil was run by gravity, and though parts of the pipe line have had to be replaced, most of the original line is still in existence and doing efficient work. Mr. Burrows also laid many other pipe lines, among which was the first line laid from Brea Canyon to San Pedro Bay. This line is still in operation. Storage tanks were erected at San Buenaventura for the storage of crude, and dock facilities were arranged for loading oil for transhipment by sea. Two wooden steamers, with inserted steel tanks, were constructed at San Francisco and put into service in 1888. They were sister-ships, one called the "W. L. Hardison," and the other the "George Loomis." These boats had a carrying capacity of 6,500 barrels each, which in those days was considered a large quantity of oil, and represented two full train loads of the small tank cars then in use which carried only 120 barrels each. Water transportation was much more economical than railroad shipment to San Francisco Bay points. As soon as these tankers were in service, the rail rate from Santa Paula to San Francisco Bay points was reduced from $1.00 per barrel to fifty cents per barrel, a rate which was maintained for many years.

The "W. L. Hardison" caught fire while standing at the wharf at Ventura and burned to the water's edge. The fire originated in the woodwork behind the overheated kitchen stove, and the inexperienced Chinese cook and crew, believing that oil tankers

were exceedingly dangerous and liable to explode in case of fire, left the boat and let it burn. The cook could have put out the fire with a bucket of water, thereby removing all danger to the crew or ship. The steel tanks which were inserted in the ship were later raised and used at the Santa Paula Refinery for storage purposes.

The "George Loomis," after an active and eventful thirty-seven years of service, is still afloat, and is now used as a barge in San Francisco Bay.

In the year 1885 Hardison and Stewart had so organized their partnership that they were getting ready to run several strings of tools, and were in need of a general superintendent of experience. John Irwin, of Pennsylvania, was invited to take the position, and accepted. He was an efficient and untiring worker. He was a good geologist and no place was too far or too inaccessible for him to go in search of prospective oil territory. Mr. Irwin held the position of field superintendent for twenty-six years, when he retired on account of his advancing age. In those days practically all of the drillers were brought out from Pennsylvania, so that California might have the benefit of their experience.

Oil wells that flowed more or less have been characteristic of the California oil fields for more than twenty-five years, but it is only in the last twelve or fifteen years that "gushers" have been developed with sufficient volume of oil to attract the attention of the world.

In February, 1892, Well No. 28, Adams Canyon, came in with an initial flow approximating 1,500 barrels per day. This was the first big well in the state, so no preparations had been made for taking care of so large a production. Before arrangements could be made to control the flow and provide sufficient tankage, the oil had run down Adams Canyon to Santa Clara River, and thence to the sea. This well produced 40,000 barrels before it ceased flowing, and was considered a phenomenal well.

In 1898 and 1899 some phenomenal gushers were developed on Section 20, T. 19 S., R. 15 E., in the Coalinga field. Prior to that time several wells had been drilled on this section, and some of them flowed, but it was not until the Home Oil Company developed its famous "Blue Goose" well that this district was looked upon

as real gusher territory. This well came in with an initial flow of 1,500 to 2,000 barrels per day. It flowed for many months, though the average production was considerably less than the initial flow. Other wells of the Home Oil Company and the Chanslor and Canfield interests were gushers of considerable size, but none of them equaled the Blue Goose well in volume of production or staying qualities.

In December, 1904, the Union Oil Company of California's Hartnell No. 1 well, located in the Santa Maria field in Santa Barbara County, began to flow a solid stream of oil through 8-inch casing. The initial flow was many times in excess of anything that had been developed previously in the state, and was the most wonderful fountain California produced until the opening of the big gushers in the Midway field in 1910. The gas pressure of this well was tremendous. The volume of oil was measured in weir boxes by a number of engineers. The actual flow of the well was 33 miner's inches, or approximately 12,000 barrels per day, this flow being maintained for about ninety days without apparent diminution. The well flowed vigorously for over two years, and produced approximately 3,000,000 barrels of oil before being put on the pump.

During the next few years several other gushers were developed in other parts of the Santa Maria field, some of which had a capacity nearly or quite equal to that of Hartnell No. 1. During the years 1909 and 1910 many wonderful gushers were developed in the San Joaquin Valley fields, particularly in the Coalinga field, and Midway district. Many of these gushers had an initial production of 15,000 to 30,000 barrels.

The largest and most spectacular well California has ever produced was Lakeview No. 1 at Maricopa. It came in with an initial production of 15,000 barrels on March 15, 1910, the production gradually increasing until May 18, when it reached 68,000 barrels. An average of 48,000 barrels per day was maintained until July 12, when the well began to decline. This well went wild, the oil was caught in open ditches, and measured through a weir. The total volume of its output was 9,000,000 barrels for a flowing period of eighteen months. After reaching its maximum daily

production of 68,000 barrels, the well gradually declined to 18,000 barrels per day. On account of the large quantities of sand which came out with the oil, the casing finally was worn through, and suddenly the hole caved in, and the greatest gusher California ever produced was dead. Though the well was redrilled it was never brought back.

Stewart and McFarland drilled, in 1888, a well near the Brea beds on the Hancock Ranch, located near the westerly limits of the city of Los Angeles. This well was a failure. The well was located on the edge of the largest Brea bed in that locality. Some years later the writer went to the Hancock Ranch to study the geology of the neighborhood, and if possible discover the cause of the failure. In examining in detail the Brea beds he discovered, on the surface of the asphalt, a mosaic of beautiful white bones, uniform in shape, lying in an exact pattern. The pattern covered an area of about 16 inches in diameter. The white weathered bones made a beautiful contrast with the black surface of the hard asphaltum. After considerable work a portion of the specimen was removed, and a search for other specimens was undertaken. Within the next day or two several skulls, many bones and vertebrae of prehistoric animals were discovered and removed. These were kept for a period of several years. Finally, after displaying the treasures to F. C. Anderson, a classmate of the writer's at college, it was decided to give the specimens to Stanford University for identification, and for display in the paleontological department. Professor J. C. Smith, in charge of the department, suggested that Professor John C. Merriam was very much interested in this class of material, which was exceedingly rare. No specimens of the kind had previously been found in the United States. Professor Merriam was extremely interested, and came to Los Angeles immediately to examine the fossils and see the place from which they were taken. He was delighted beyond measure, and his enthusiasm for further research in the Brea beds was unbounded. He secured from the Hancock estate a lease on 2 acres of ground, and soon began his excavations. In a short time, news of the discovery spread throughout the United States and Europe, and within three months, through the courtesy of Allen

Hancock, more than a dozen different institutions were working to uncover other specimens. Mr. Hancock very wisely allotted to each institution a particular area which it might explore. The entire area of the Brea bed, comprising some 20 acres, was divided up into several parcels resembling the claims in the early day gold-mining district. This work was carried on persistently for about two years, and the amount of material taken out was very large.

About three hundred complete skeletons of saber tooth tigers, many mastodons, elephants, bison, horses, wolves, foxes, condors, turkeys, peacocks, and innumerable smaller animals were recovered. The Brea beds proved to be the richest find of material of this kind ever uncovered in the world. The preserving qualities of the asphaltum kept the bones from weathering, and all the remains were found in a perfect state of preservation. A very complete display of these prehistoric and extinct animals may be seen in the museum at Exposition Park, in Los Angeles. Many others were taken to the Smithsonian Institute and to the University of California.

Romance had not yet gone from California. In 1893 E. L. Doheny, with his own hands, made hand-dug pits in what is now known as the Los Angeles oil field, from which he produced commercial oil. After the demonstration by Mr. Doheny, shallow wells were soon drilled, and in a period of two or three years several hundred wells had been drilled, and there was an overproduction in this vicinity. This oil was of heavy character and fit only for fuel. The discovery of this field by Mr. Doheny, which resulted in the first big overproduction, was really the beginning of the fuel oil business. The price for this kind of oil soon dropped to twenty-five cents per barrel, and the only way to dispose of this fuel oil was to build up enterprises which would use it. Oil-burning apparatus was introduced into the stationary power plants in the city. An endeavor was made to induce the railroad companies to put fuel oil on the locomotives, but the railroad companies were skeptical and doubted whether oil could be used successfully. If the railroad companies could be induced to use it on all their locomotives it was believed by the oil operators that a constant demand for the oil would be created.

The Union Oil Company of California was first to undertake the work of demonstrating the desirability of liquid fuel for locomotives. It arranged with the Santa Fe Railroad to remodel one of its engines. An oil tank was placed on the tender, and an oil burner was installed. Trial trips were made on the branch line running from Saugus to Santa Barbara, but the first installation was not a success. Finally, E. A. Edwards was called in and installed a forced feed burner with a steam jet. The flame soon put a blister on the boiler, this difficulty being finally overcome by building up baffle walls of fireproof material. After six months' trial it was found to be entirely successful, and soon after the Santa Fe and Southern Pacific Railway companies installed apparatus for burning fuel oil. The demand for Los Angeles crude was greatly increased, and the project declared an unqualified success. Improvements in the oil burners have been made from time to time, but the original principle of the burner has remained very much the same.

Mr. Doheny was the real discoverer and developer of both the Los Angeles field and the Olinda pool in Orange County. He also played a very important part in the early history of the Kern River and other fields in San Joaquin Valley. His greatest successes were attained during the past twenty years in the development of his Mexican properties, which have been the wonder and admiration of the world. By reason of his perseverance and foresight he is one of the outstanding figures in the history of oil today.

Although the production of oil is today the greatest industry on the Pacific Coast, and one of the essential industries of the world, whether at peace or war, it has arrived at its present gigantic proportions through many vicissitudes. In the period up to 1900, there were many dark days for the oil men of California, Markets were poor, public interest was faint, pioneering was expensive, and financially the oil business had not yet arrived. Only the vision, the courage, and the sacrifices of the "oil pioneers" which enabled them to "carry on" in the face of discouragement and hardships, which would have daunted men of weaker breed, saved the oil industry for this generation.

THE RÔLE OF THE GEOLOGIST IN THE DEVELOPMENT OF THE CALIFORNIA OIL FIELDS[1]

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The first developments in the California oil fields took place close to the more conspicuous seepages, many of which are of very large extent. Some are associated with the monoclinal folds where the oil sands outcrop; other extensive seepages occur in or adjacent to the fields which are associated with faults of considerable magnitude. In the Ventura fields there are accumulations of tar and brea several acres in extent. In some cases where seepages occur on hill sides, streams of tar may be seen which extend down the canyons for almost a quarter of a mile, and it is quite natural that seepages of this kind should have attracted early attention. There are also extensive seepages at Coalinga and McKittrick. At McKittrick the accumulations of tar and brea were worked by open cuts and pits for paving asphalt prior to any oil development by means of wells. The Southern Pacific Railroad had built a branch line from Bakersfield to Asphalto for the purpose of handling this material. The early history of California development has been described by W. W. Orcutt.[2]

In 1899 the total production of the state of California was 2,677,000 barrels. In the year 1902 it was 14,357,000 barrels. In 1899 the Union Oil Company of California established its geological department with Mr. Orcutt at its head, though it was not in full working order until the following year, when development started in the Santa Maria field. The first wells of the Western Union Oil Company were developed from shallow sands at the base of the Fernando formation along the flank of a well-developed structure in the Monterey. The Union Oil Company acquired extensive

[1] Read before the Association at the Los Angeles meeting, September, 1923. Manuscript received by the Editor, November, 1923.

[2] This *Bulletin*, p. 61.

holdings on the main structure where they developed a number of very valuable properties.

In 1898 the Southern Pacific sold a number of sections of railroad lands at Coalinga for $2.50 an acre. One of these sections subsequently produced 35,000,000 barrels of oil. Prior to this time the Southern Pacific Company had organized a geological department which was doing work in Texas and Mexico. When the value of these lands began to be realized, reconnaissance work was started in California. In 1903 the Kern Trading and Oil Company was organized to operate on the grant lands. At the same time the geological department established a branch office in San Francisco, and started the systematic work of classifying the railroad lands.

From the start this company was controlled by technical men, for E. T. Dumble, geologist, was the manager and M. E. Lombardi, a mining engineer, was superintendent of development. This organization has always taken the lead in the matter of technical management. As early as 1907 they put resident geologists at each of the fields where they were operating and started the study of subsurface problems. The question of the water shut-off and finishing of wells was studied by means of cross-sections and these problems were handled in a manner considerably in advance of the practice of the times.

In 1908 the Associated Oil Company organized a geological department and began a series of extended field investigations, which were related chiefly to the acquisition of new properties and had nothing to do with the operating problems at the properties under development.

At about the same time the Standard Oil Company organized a geological department which handled the acquisition of new properties and had but little to do with the producing department in the problems of oil development.

In 1907 the United States Geological Survey published *Bulletin 309*, "The Santa Clara Valley, Puente Hills and Los Angeles Districts," by John H. Eldridge and Ralph Arnold. Mr. Eldridge's field work on this bulletin was started in 1901; the field work was completed and the bulletin prepared by Ralph Arnold in 1905. During the succeeding years a number of important bulletins

were published by the Geological Survey on the various California fields: "The Santa Maria Oil District of California," by Ralph Arnold and Robert Anderson, in 1907; "The Coalinga Oil District," by the same authors, in 1908; "McKittrick-Sunset District," by Ralph Arnold and Harry R. Johnson, in 1910.

The California State Mining Bureau has been a very important factor in the development of the oil industry in California. As early as 1888 the report of the State Minerologist devoted attention to the Oil Fields of California. *Bulletin 3*, by W. L. Watts, "Oil and Gas-Yielding Formations of Central California," was published in 1894. This was followed by a number of other publications on the oil fields of the state. In 1914 *Bulletin 69*, by R. P. McLaughlin, covered not only the geology of all the fields producing at that time, but also included various technical phases of oil field operations.

Probably the most important single event in the evolution of California field practice was the establishment, by the legislature in 1915, of the Department of Oil and Gas under the jurisdiction of the California State Mining Bureau. This Department was organized primarily for the purpose of supervising oil field operations, with special reference to the matter of shutting off water in the oil fields and conserving the state's oil and gas resources. The State Oil and Gas Supervisor is authorized to collect field information, to inspect the water shut-off in drilling wells and to direct and inspect the abandonment of old wells. The establishment of this department was the outcome of attempts for several years to control these matters by associations of producers under the authority of county inspectors who had no power to enforce their rulings. This department is supported by a special tax on the oil industry. The Oil and Gas Supervisor has headquarters in the Mining Bureau at San Francisco. The state is divided into five districts with a deputy in charge of each district. The work of the department has grown until the department now employs a number of petroleum engineers and inspectors who look after the work in each of the separate fields.

Important as has been the work of the bureau in collecting and systematizing information as to the underground conditions in the fields, of even more importance was the reaction on general

field practice. The larger operating companies, who had prior to that time used their geological departments only in connection with the acquisition of new property, one by one followed the lead of the Southern Pacific people and placed resident geologists in the field to collect information and study the subsurface conditions with relation to their own drilling operations and producing problems. Today there are but few companies carrying on active drilling operations who have advanced beyond the one-well stage, that do not depend on geological advice in handling their drilling problems. Several of the drilling contractors have a geologist in their organization whose duty it is to determine the setting points for strings of pipe.

The large majority of the important discoveries since 1900 have been developed by the larger organizations as a result of careful geological study. (1) Beverly was discovered by the Associated Oil Company in 1907. (2) West Coyote was drilled in 1908 by one of the independent operators. The water was not shut off and the property was acquired by the Standard Oil Company in 1912. (3) The Buena Vista Hills were developed by the Honolulu Oil Company on the recommendation of F. M. Anderson. (4) Lost Hill was discovered by an independent operator in 1910. The structure had been mapped by the U.S. Geological Survey but the depth figured as excessive. The structure had been known to several of the larger organizations for a number of years prior to this time. (5) East Coyote was discovered by the Associated Oil Company in 1911. (6) Belridge was discovered in 1911 by an independent operator by finding an outcrop of oil sand. (7) The two important domes south of Santa Clara River were mapped by the Geological Survey and published in 1905. The Montebello field was developed in 1911 by the Montebello Oil Company and the South Mountain field in 1915 by the Oak Ridge Oil Company. Both of these companies were under the same management, and their first manager and field superintendent were geologists and engineers. (8) The Ventura anticline was discovered by an independent operator in 1915. (9) The Montebello oil field was discovered by the Standard Oil Company in 1917. This structure

was mapped by the California State Mining Bureau in *Bulletin 69*, which was published in 1914. (10) The Richfield oil pool was discovered by the Union Oil Company in 1919. (11) The Elk Hills were known to the geologists of several of the larger companies as early as 1908. They were mapped by the Geological Survey and withdrawn from entry by President Taft in September, 1909. They were the subject of much controversy in the courts during the suit brought by the federal government against the Southern Pacific Company to cancel patents to grant lands. The first actual production was brought in 1919 on the two school sections which had been purchased by the Standard Oil Company of California some years prior to this time. (12) Huntington Beach was discovered by the Standard Oil Company in 1920. (13) Long Beach was discovered by the Shell Company in 1921. (14) Santa Fe Springs was discovered by the Union Oil Company in 1919, though it was not a real success until the Bell well came in in 1921. (15) Torrance was discovered in 1922 by the C. C. M. O. Co. (16) Wheeler Ridge was discovered in 1922 by Standard Oil Company.

Of the sixteen fields mentioned, twelve were discovered by companies with regular organized geological departments, while four were discovered by operators who were acting on other advice.

There is a long list of dry holes which have been drilled on competent advice. Many of these were no doubt recommended as long shots. There are important structures which have attracted wide attention because they gave excellent promise of production. The Kettleman Hills and the Inglewood Hills both have resulted up to the present time in deep dry holes.

Space does not permit an attempt to give complete lists of the discoverers of our California fields. To the writer's own knowledge several of the more obvious of the California structures were known to more than one of the independent geologists and to the geological staffs of some of the larger organizations for a number of years before any attempt was made to develop them. It will be remembered that the anticlinal theory of the accumulation of oil found acceptance, for a considerable period, in the minds of the profession, before it was given much weight by the operators who controlled

the oil industry. Who is there among the geologists with ten or more years' experience in California who cannot remember some tract of land situated on a well-developed dome in Middle Tertiary strata, which was recommended for purchase in fee for prices ranging from $75 to $200 per acre? Sometimes, these recommendations were followed and sometimes they were not. More often these structures subsequently produced from 25,000 to 75,000 barrels per acre than in the cases where they did not.

GEOLOGICAL NOTES

GAS NEAR FORT COLLINS, COLORADO

INTRODUCTION

Gas in large quantities, at a depth of 4,285 feet, has been encountered by the Union Oil Company of California on the Wellington structure, north of Fort Collins, Colorado. On November 18, 1923, the well gauged 82,000,000 cubic feet per day. The well is located in the SW¼ of NW¼, Sec. 31, T. 10 N., R. 68 W., about six miles north and two miles west of the town of Wellington, and fourteen miles north and two miles east of the city of Fort Collins. The gas is coming from the "Niobenton" or "Wall Creek" sand in the top of the Benton, immediately underlying the Niobrara.

The Union's well was started in the early summer, and made rapid progress. At around 4,200 feet the cuttings became heavily saturated with oil and at 4,285 feet, having just touched the sand, the well began to make about 3,000,000 cubic feet of wet gas. This was at 3:30 on the morning of November 11. On the afternoon of the twelfth the well was spraying a slight amount of oil; at 4:00 that afternoon it blew itself in as a tremendous gasser. On the evening of the thirteenth the flow was said to be still increasing, and when gauged on the eighteenth, the flow was unabated. The gas is reported to be wet, but no analyses are yet available.

HISTORY

In 1907 or 1908 Junius Henderson of the Colorado Geological Survey recognized the existence of anticlinal folding west of Wellington. During succeeding years his references to this folding and its possible importance led to a number of visits to the area by members of the survey, including the making of a sketch map in 1915 by R. Clare Coffin.

Possibly the members of the survey called the folding to the attention of S. F. Rathvon, an oil operator of Boulder, or perhaps Mr. Rathvon, who was handy with a Brunton, discovered the anticline for himself. At any rate he organized the Poudre Oil and Gas Company, which in 1915 located and drilled a well in the SW¼ of NE¼, Sec. 31, T. 9 N., R. 68 W., six miles south of the present well, at about the only point on the anticline where the dip in both directions is plainly visible. Unfor-

tunately the location, though on the anticlinal axis, is in a saddle between two crests, and is not within a closed area. The well was drilled to nearly 4,000 feet, ending in the Steele shale after obtaining showings of oil and gas.

In June, 1915, R. C. Hills reported favorably on the area, calling it the Box Elder anticline. He reported the Rathvon location as good geologically as any other, and stated, "The fact is, unless all signs fail, the Box Elder field will prove, when developed, a much bigger producer than the Salt Creek field of Wyoming." In September, 1915, C. A. Fisher also reported favorably on the area. He recognized that the Rathvon location was on the south end of the fold, but, not having contoured the structure, failed to recognize that the well was outside the closure. He placed the depth to the Niobenton at 3,400 to 3,500 feet, and concluded, "I see no reason why this anticline should not produce oil and gas in commercial quantities."

In a report of May, 1916, R. D. George, state geologist, gave Mr. Rathvon an excellent description of the Wellington structure, noting the crest in Sec. 31–10–68 and the plunge southward from there to the well in Sec. 31–9–68, and definitely closing the structure to the north. He failed to recognize that the Rathvon well was outside the closed area, gave as the reason for its failure that it did not reach the sandy zone at the base of the Pierre, and concluded, "The anticline merits a more thorough test."

In the fall of 1917 John G. Bartram, on a reconnaissance of the Rocky Mountain front for the Rocky Mountain Division of the Roxana Petroleum Corporation, made an independent discovery of reverse dips and recommended further work. A. T. Spring, who had been Bartram's assistant, was sent into the area and reported a pronounced anticline running from near Fort Collins northward for about fifteen miles, and outlined the area which includes the Wellington and Fort Collins structures. This appears to have been the first definite recognition that the anticline extended south through what is now recognized as the Fort Collins dome. The Roxana promptly leased about 14,000 acres and started detailed work, under A. T. Schwennesen, by E. W. Krampert and C. H. Henley, assisted by F. E. Wood and J. A. Laurin. The mapping was done in great detail and involved several months work. Much of the area is irrigated farming country, and it was necessary to examine every creek, dry gulch, and irrigation ditch, and to dig many pits in order to work out the structure. The resulting map has been the basis for

practically all activities in the region since that time, and careful checking by various geologic staffs has not modified it to any great extent.

In August, 1919, the Roxana made an acreage arrangement with the Keoughan-Hurst Drilling Company for a test of the Hygiene, or basal Mesaverde, sand. It was located about 300 feet northeast of the present Union well, was drilled to a depth of 1,312 feet, and was abandoned after obtaining some water and a little oil in the Hygiene. The Roxana's Rocky Mountain staff recommended a well to the Niobenton or Wall Creek, but the aversion of the London office to depths greater than about 3,000 feet, and possibly the adverse opinion of a geologist from the Hague, led to the abandonment of the Roxana leases, without further drilling, in the fall of 1920, after a number of unsuccessful attempts to turn the leases to other companies.

Not long thereafter, Thomas S. Harrison had Victor Hendrickson examine the area and later examined it himself. Harrison's report stated, "The structure itself is quite favorable to oil and gas accumulation. . . . . I recommend that a well be drilled." A syndicate of which Harrison was a member leased up the area and, after several attempts to interest different companies, took the matter up with Roderick Burnham of the Union Oil Company of California. Burnham went over the area with Harrison and was so favorably impressed that he ordered a field examination. James M. Douglas, assisted by Sam Grinsfelder, examined the area for the Union and recommended it very strongly to his company for drilling.

LOG OF THE WELL

On the following log of the well the writer has indicated his own guess as to the geologic formations penetrated, as the Union driller did not keep a log on which formation boundaries can be noted with any degree of certainty. A comparison of the upper 1,300 feet of this log with the log of the near-by Roxana-Keoughan-Hurst well, which was kept by geologists, shows why well-log correlations are sometimes difficult to make. The two wells started within a few feet of one another stratigraphically.

It is interesting to note that, despite difficult conditions for measurement, C. H. Wegemann estimated the depth to the top of the Benton sand at 4,300; T. S. Harrison at 4,300 to 4,500; James M. Douglas at 4,306; and E. W. Krampert, C. H. Henley, E. L. Jones, Jr., John D. Northrop, and F. F. Hintze at 4,100 to 4,400.

TABLE I

LOG OF UNION OIL COMPANY'S WELLINGTON WELL

SW¼ OF NW¼, SEC. 31, T. 10 N., R. 68 W., COLORADO

Formation	Top	Bottom	Thickness
Mesaverde:			
Brown gumbo	0	8	8
Quick sand—water	8	20	12
Brown gravel	20	30	10
Brown, sandy shale	30	38	8
Yellow clay	38	45	7
Blue shale	45	65	20
Gray, sandy shale	65	170	105
Gray shale	170	455	285
Gray, sandy shale	455	475	20
Gray shale	475	540	65
Gray, sandy shale	540	570	30
Sandy formation with water (about 2 barrels per hour)	570	585	15
Gray shale	585	875	290
Gray sand—water	875	967	92
Gray shale	967	1015	48
Gray, sandy shale	1015	1075	60
Gray shale	1075	1095	20
Gray, sandy shale with streaks of sand	1095	1120	25
Steele:			
Gray shale	1120	1248	128
Hard shell	1248	1253	5
Hard shale	1253	1460	207
Gray shale	1460	1720	260
Soft, gray shale	1720	1840	120
Gray shale	1840	1950	110
Hard, gray shale	1950	2255	305
Gray shale	2255	2400	145
Gray, sandy shale	2400	2415	15
Gray shale	2415	2440	25
Sticky, sandy shale	2440	2530	90
Brown, sandy shale	2530	2555	25
Gray shale	2555	2566	11
Hard, dark shale	2566	2574	8
Hard, gray shale	2574	2600	26
Stocky, gray sand shale	2600	3030	430
Gray shale	3030	3060	30
Sandy, gray shale	3060	3220	160
Gray shale	3220	3230	10
Gray shale with thin sandy strata	3230	3260	30
Gray shale	3260	3445	185
Hard, gray shale with shells	3445	3485	40
Hard, gray-and-brown shale	3485	3570	85
Niobrara:			
Limy, gray shale	3570	3730	160
Sharp, gray sand	3730	3733	3
Sandy, gray shale	3733	3775	42
Dark and gray shale and shells	3775	3855	80

TABLE I—*Continued*

Formation	Top	Bottom	Thickness
Niobrara:			
Dark, soft, muddy shale	3855	3875	20
Soft, dark gray shale	3875	4010	135
Hard, gray shale	4010	4040	30
Gray shale	4040	4120	80
Soft, dark gray shale	4120	4225	105
Hard, gray shale	4225	4235	10
Gray shale	4235	4285	50
Benton:			
Top of sand—gas	4285		

GEOLOGY

Sequence.—The Cretaceous rocks of the region are as follows:

			Feet
Laramie			600–1200
Montana	Fox Hills		600–1200
	Pierre	Lewis	1500–2500
		Mesaverde (5 or more sands; Hygiene sand at base)	1740
		Steele (Shannon sandy zone in lower half)	2450
Colorado	Niobrara		700
	Benton ("Niobenton" or "Wall Creek" sand at top)		600–650
Dakota group (contains the Muddy, Dakota, and Lakota sands)			350–400

Sandstones in the Mesaverde.—Prior to the Roxana's work in this area, the Mesaverde formation was not considered to exist east of the Front Range. The Pierre, instead of being divided into Steele, Mesaverde, and Lewis, as in western Colorado, New Mexico, and Wyoming, was supposed to extend from the top of the Niobrara to the base of the Fox Hills in a shale series broken only by a single sandstone known as the Hygiene. Intensive work along the Rocky Mountain front from north of Cheyenne to south of Boulder proved, however, that the isolated outcrops which had been joined together and mapped as Hygiene represent, instead of a single sandstone, a series of sandstones occupying a stratigraphic interval of 1,700 or more feet, interbedded with shales considerably more sandy than those in the lower and upper parts of the Pierre. In other words, the work of Schwennesen, Krampert, Northrop, and Harnsberger demonstrated the existence of Mesaverde lithology along the Rocky Mountain front in northern Colorado and southern Wyoming. It should be noted, however, that whereas the Mesaverde

of other localities is predominantly of fresh water and brackish water origin, the Mesaverde of this region seems to be wholly marine.

The more prominent sandstones of the series were identified, named, and mapped in the Fort Collins region by Schwennesen, Krampert, and Henley. The following section of the Mesaverde, measured by Henley and checked by Wegemann, gives the names, positions, and thicknesses of the sands, and the interbedded shales.

SECTION OF THE MESAVERDE FORMATION NEAR DOUGLAS LAKE, COLORADO

Richard sandstone	59
Shale, sandy	171
Larimer sandstone	141
Shale	163
Rocky Ridge sandstone	97
Shale	604
Terry sandstone	16
Shale	383
Hygiene sandstone	100
Total Mesaverde	1734

The Richard sandstone is exposed along the north bank of Richard Lake in Section 30–8–68. The Larimer[1] sandstone is exposed in the Larimer county canal in section 24–8–69, on the west flank of the Fort Collins structure, or it may be studied to better advantage, north of the Colorado and Southern track about a mile east of the village of Waverly. The Rocky Ridge sandstone forms a prominent cliff around the north and east banks of the Rocky Ridge Reservoir, and is also prominent in the cliff outlining Douglas Lake on the east. The Terry sandstone forms part of the island in Terry Lake, and also helps to form two of the promontories jutting into the lake.

The name "Hygiene" has been in use for many years to designate a sandstone in the Pierre. Presumably it comes from an exposure near the town of Hygiene, west of Longmont. Unfortunately, the assumption seems to have been that only one sandstone was present in the Pierre, and every sandstone outcrop was called "Hygiene" and connected up in a single line across the map. Thus sands occurring through a wide stratigraphic interval were joining together and called "Hygiene."

[1] Schwennesen, Krampert, and Henley call this the "Waverly" sandstone, but as this name has been applied elsewhere to other rocks, the name "Larimer" has been substituted.

Schwennesen, Krampert, and Henley restricted the name to the basal sandstone of the series, since this seems most likely to have been the sandstone noted near Hygiene, and the term is so used here.

That other sandstone lenses are present here and there in the interbedded shales of the Mesaverde, and that the sandstones just described are not uniform in thickness, is shown by comparing the lower part of Henley's measured section with the following log of the Roxana-Keoughan-Hurst well, as recorded by R. W. Gibson and G. E. Miller, Roxana geologists. The well started just below the Rocky Ridge sandstone.

TABLE II

LOG OF ROXANA-KEOUGHAN-HURST WELL

NW¼, SEC. 31, T. 10 N., R. 68 W., COLORADO

Formation	Top	Bottom	Thickness
Yellow clay	0	18	18
Soft, gray shale	16	415	397
Sandy shale, getting darker and harder	415	578	163
Fine-grained gray sandstone, carrying small amount water; first real oil colors at 590'	578	598	20
Soft, gray shale	598	885	287
Fine to coarse-grained gray sandstone, showing oil and water	885	960	75
Shale, gray	960	1010	70
Sandy shale	1010	1020	10
Gray sandstone	1020	1038	18
Gray shale	1038	1080	42
Gray sandstone (same as 885 to 960)	1080	1112	32
Black shale	1112	1312	200
Well abandoned and casing pulled	1312		

Possible Shannon Zone.—In the Steele, about 1,500 to 2,000 feet below the Mesaverde, is a zone of sandy shales and thin sandstones, possibly representing the Shannon horizon of Wyoming. At the outcrop a few miles northwest of the structure sandy material makes up 30 to 50 per cent of the beds in this zone, and one sandstone is about 20 feet thick. It is difficult to recognize this zone in the log of the Union well, which, as already pointed out, is very unsatisfactory.

Sandstone in the Benton.—The sand at the top of the Benton, in contact with the Niobrara, has also been the subject of some argument. Some geologists assume that the Carlile shale, which in Wyoming lies between the top of the Frontier and the base of the Niobrara, has thinned out southward, and that this sand is the equivalent of the Wall Creek (Frontier) sand of Wyoming. More cautious geologists are designating it the "Niobenton" sand without attempting correlation. The Wall

Creek correlation is supported by the finding, a short distance below the sand, of *Inoceramus labiatus*, which is characteristic of the Greenhorn limestone, the Black Hills equivalent of the lower (?) Frontier. The sand varies from 10 to 30 feet in thickness between the Wyoming line and Boulder. As a rule it is quartzose, fairly coarse, rather porous, and, despite its contact with the limestones of the Niobrara, rather free from lime.

Sandstones in the Dakota Group.—A section of the Dakota group in Owl Canyon about ten miles west of the Wellington structure is given by Willis T. Lee[1] as follows:

	Feet
Upper sandstone	40
Middle shale	195
Middle sandstone	12
Lower shale	64
Lower sandstone	75

The upper, middle, and lower sandstones of this section correspond to the Muddy, Dakota, and Lakota sandstones of southern Wyoming.

Surface Rocks.—The surface rocks of the structures are Lewis and Mesaverde. The crest of the Wellington dome is in the Mesaverde about 1,100 feet above the base; the crest of the Fort Collins dome in the Mesaverde, about 1,400 feet above the base. Lewis shales occupy the east flanks of both structures, the saddle between them, and the deep syncline between the saddle and the Douglas Lake fold. The crest of the Douglas Lake dome is in the Mesaverde about 1,000 feet above the base.

The Structures.—As to structure, the work of Schwennesen, Krampert, and Henley shows an anticlinal axis, slightly sinuous, running from a point about 3 miles east of Fort Collins, nearly due north for about 15 miles. On this axis are two crests, one lying northeast of Fort Collins, and the other northwest of Wellington. Each is nearly 5 miles long and 1 to 1½ miles wide within its lowest closing contour. The Wellington crest has a closure of between 500 and 600 feet, and a closed area of about 2,100 acres; the Fort Collins, a closure of between 400 and 500 feet, and a closed area of about 1,400 acres.

West of the saddle between the two is a smaller dome known as the "Douglas Lake" structure, about 2 miles long and ½ mile wide, with a probable closure of about 200 feet.

[1] Willis T. Lee, *U.S.G.S. Bull. 751-A*, p. 6.

The Rathvon well, as already stated, was drilled on the anticlinal axis, but near the bottom of the saddle between the Fort Collins and Wellington domes.

PROSPECTS

The interval from the top of the "Niobenton" to the top of the Dakota group is, according to a number of sections by various geologists, 600 to 650 feet. Thus the Muddy sand, the uppermost sand of the group, would be encountered at about 4,900 feet, and the Dakota group would be penetrated at about 5,300 feet. The shales of the lower Benton and the upper Dakota appear to be exceptionally bituminous in this region.

The oily character of the shales just above the "Niobenton" in the Union well and the fact that the well sprayed a slight amount of oil before it blew itself in, offer some ground for thinking that oil may yet be found in the "Niobenton" sand. At any rate, an enterprise which has been watched with a good deal of interest has been brought to a successful conclusion, and the State of Colorado has at last achieved a commercial gas field. Whether the flanks of the structure will prove to carry oil in the "Niobenton," whether the lower-lying Fort Collins structure will have oil on crest or flanks, or whether the sands of the Dakota group will prove to be oil-bearing remain to be seen.

FURTHER NOTE ON WELLINGTON

About a week after the well came in it started spraying a high grade of green oil. The amount of oil has steadily increased, and the well is now reported to be making about 400 barrels per day. Most of the geologists of the Rocky Mountain region feel that Wellington will be an oil field rather than a gas field, though there does not seem to have been a decrease in the amount of gas.

STILL FURTHER NOTE ON WELLINGTON

Some geologists are swinging to the opinion that the productive sand is not the Wall Creek or Niobenton but the Muddy, the uppermost sand of the Dakota group. To date the weight of evidence remains in favor of the Niobenton, but it will not do, as yet, to be too dogmatic about it.

MAX W BALL

THE IMPORTANCE OF WATER ANALYSES

Not only in my "Watersupply Papers" Nos. 30 and 31 of the *U.S. Geological Survey*, and on the field assay of waters and on "Minewater Composition, an Index to the Course of Ore-bearing Currents" in

Economic Geology, but by Rogers and numerous others in the *A.I.M.E.*, has the importance of the variations in composition in the waters associated with oil been shown. Horizons may be followed across structure (Powers), changes in composition may indicate the presence of oil (Rogers) and may distinguish between top and bottom water, indicate leaky casing, etc.

It has, however, become clear that the interpretation of such waters is a matter of difficulty. Beside the circulation due to drilling, and from the present surface, circulation from surfaces of unconformity in past geological eras finds expression in the deeply buried waters of today.

The originally buried, connate waters are also not necessarily marine, and the composition of the ocean should have varied—seems to have varied—during geological time. At present the composition of the ocean does not vary much from pole to pole, and probably the composition of the open ocean has never been very different in different places. It would therefore be of great interest to determine what that composition was at various geological epochs. No doubt changes have taken place since burial, but would it not be possible to eliminate these changes and the factors above cited, and by comparing the analyses of waters found in different kinds of rocks and in widely different regions so eliminate these variations as to get some idea of the composition of the ocean in which the marine strata were laid down?

Organic matter may have precipitated the sulphate as pyrite, and evaporation may have precipitated the sulphate as anhydrite or gypsum. Lime and magnesia have gone out with carbonate as calcite and dolomite. Soda from the decomposition of the rocks is ever being brought in. Is it ever removed in anything but salt? Is albitization a widespread diagenetic process? Is chlorine removed except in salt, and what is the source of the chlorine? How has the ratio of source to supply varied in geologic time? These are some of the questions upon which a comprehensive study of water analyses might throw light. May I ask the help of any who can give me analyses of waters of fairly known geologic age, published, especially if off the beaten lines of bibliography,[1] but especially unpublished analyses from waters relatively deep and stagnant, and especially from out-of-the-way places.

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[1] I have access here at Boston to the *A.I.M.E.*, Reeves's thesis, and the geological surveys.

GEOLOGICAL FEATURES ILLUSTRATED BY MODELS

The use of models by engineers to illustrate geological conditions probably originated in the mining industry during the early litigation growing out of our Apex Law. The difficulty of showing geologic shapes and planes by the usual conventional signs in two dimensions only, and the consequent befogging of the minds of non-technically trained judges, attorneys, and juries, resulted in various attempts to solve this problem by means of three-dimensional models. Some of the famous models built and used for such purposes cost thousands of dollars. One of the most costly of these models was built by the engineers of a company whose right to a certain mining property had been attacked; but in this case they failed to convince the judge, and the property was lost to the plaintiff. The model, however, at the same time had convinced the engineers of the plaintiff company that the solution it illustrated was the correct one, and after obtaining possession of the mine they planned and carried out a program of exploration on this basis which resulted in the discovery and development of a large ore body.

Models of coal mines, built to scale, are more or less common, and some of the important metal mines of this country keep models of their entire underground workings in a fairly up-to-date condition at all times. Plans for exploration and development work are made with the model before the manager. In some cases, small temporary and local models are constructed from time to time, to help in the solution of problems as they arise in the mine.

Models of various sorts have been used for similar purposes in the oil country, although their use has been much more restricted until recently. This is probably because until recent years the use of geology was little understood by this industry.

Another field for the use of graphic models is in the classroom in those institutions where courses in various forms of applied geology are given. These are usually topographic models, upon which are drawn or painted the areal geology, although more recently there have been constructed several models at the University of Pittsburgh, which will be described in this paper.

The construction of extensive canal and irrigation systems, or water-power projects, sometimes involves topographic and geologic features which can best be illustrated by models. Examples of such miniature models are those made of the watershed of the Chagres River and the Panama Canal, and the projected Erie-Ohio canal.

Of course, the building of models for museums serves another very special purpose which need not be discussed here. Some of these are very beautiful and elaborate, and require the work of specialists for long periods.

At least one of the large companies operating in the Mid-Continent field uses various sorts of models in both their exploration work and also in the intensive development of their own properties. The construction and use of these models is under the direction of their chief geologist. This is the most important field, and can be expanded to include liaison work between the geologist and company executives or boards of directors.

The use of peg models was seemingly originated in California by the State Mining Bureau, in connection with the attempt to control the water in the Kern River district. One of these was on exhibition at the San Francisco Exposition. Since that time similar models have been constructed in other oil fields. This type is adapted to progressive construction as the field develops, and has been used by the U. S. Bureau of Mines at Hewitt and Deaner in Oklahoma, in their educational work in co-operation with the companies in those oil pools. The public has thus become more or less familiar with this type of model.

The uses to which graphic models have been or can be adapted may be summarized as follows: (1) mine planning and development; (2) court-room use, and liaison work between attorneys and engineers in building up a legal case; (3) liaison service between company geologists and executives or boards of directors; (4) general service in clarifying contour maps, to the geologist for his own help, and to the layman; (5) appraisal work, in special cases, and estimation of reserves; (6) classroom illustration, in both mining and oil geology; (7) museums, and general educational use, perhaps including those models constructed for state and national commissions considering large public projects.

Different types of models may be adapted to various purposes, and may be listed as follows:

1. Skeleton mine models, in which the various workings and veins are shown by means of wooden or metal stocks or rods, with the surrounding country rock left out. These are very complicated, and confusing in general appearance. They cannot be read or understood without careful explanation, are difficult of construction, and as a rule very fragile. On the other hand, all parts of the model are visible from any angle, and additions can be made from time to time, as development proceeds.

2. In oil field peg models the wells drilled in the district are shown by upright pegs inserted in a board, which may or may not have the

pay formation shown in relief. These are sometimes constructed with a surface section, which may be transparent, upon which is drawn a map of the property lines. The different formations passed through are usually shown directly on the pegs by colors or symbols, and are often connected one to the other by colored strings, thus showing dips between wells. Such models have both the advantages and disadvantages of the skeleton mine models described above, although they are usually not so complicated nor so fragile.

3. Plaster relief models are usually built by cutting out flat contour sections of cardboard or wood, and superimposing them one on another. The resulting terraces and irregularities are filled in with clay, putty, or some composition, the finer detail added, and then cast in plaster, or perhaps the original is finished and painted. Such models may be used to represent surface topography, or contoured sub-surface geology, or both—through removable sections. They are not adapted to easy modifications, and therefore not used in development work. Plaster models have been made of mine workings, illustrating vertical sections cut through the earth, and showing vein structure in relation to workings present and projected; and possibly also surface topography. Such models are the best possible picture of actual conditions in miniature, and great refinement can be used in their construction. Attention can be concentrated on particular points in a very graphic manner. Once built, however, they are very difficult to modify, and at best only show a very limited number of vertical sections underground.

4. Sometimes mine models are constructed of transparent sheets of celluloid or glass representing different levels, upon which are drawn the veins and workings at each level. These are usually held in a frame, and may be intersected by colored strips and planes representing the various veins and vertical raises, winzes, etc. This transparent section has been used for oil field models to show the surface land lines in which is inserted the pegs representing wells.[1]

5. Combinations of any of the above types can be constructed to cover special conditions.

Two models have recently been constructed at the University of Pittsburgh, illustrating the important structural features of the Appalachian-Illinois and the Mid-Continent oil fields (Fig. 1). These were built by Paul Ruedemann and the author, and there is under construction a similar model of the Northwest Plains region. The first is based upon the top of the Clinton sand or its equivalent (Fig. 2),

[1] L. G. Huntley, *Amer. Assn. Petrol. Geol. Bull. 6*, Vol. 5, pp. 677–78.

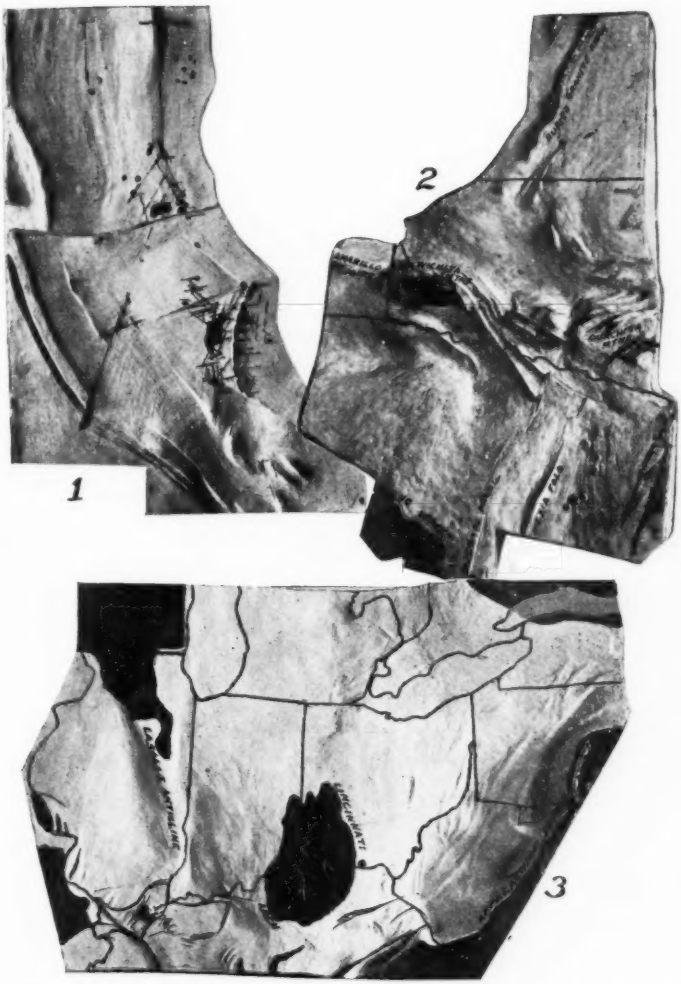
with a horizontal scale of 16 miles to the inch. The second is based upon the top of the Mississippi lime or its equivalent, with a horizontal scale of 12 miles to the inch (Fig. 3).

In making the first model, an original was built up with pasteboard shapes cut out from a contour map of the region, and the surface smoothed with modeling clay. The whole model was then cast in plaster, and further detail added by cutting into the plaster. The legend was then shown in colors, and the model varnished to preserve the surface.

The Appalachian model was started in the same manner, but instead of using modeling clay the surface and detail was finished in putty, and the original model completed instead of having a cast made in plaster. This saved time and expense, and made possible later additions and modifications, which would not have been possible in the plaster. A vertical section of the formations above the Clinton was constructed, showing the divergence or thickening of the beds eastward across the Appalachian Basin. This was finished in the same manner as was the model, but as a separate section which could be fitted on by means of guide pegs. The upper edge of this thin upper section was shown by a surface profile to the same scale.

While some generalizations had to be made in the building of these two models, they are fairly correct in the main features. They give a very satisfactory picture of structural conditions, and as they can be added to from time to time, furnish valuable material in the Course in Oil and Gas Production at Pittsburgh. The only alternative to the use of such models is the exhaustive searching through widely scattered sources for isolated bits of material bearing on each district. The student is totally unfamiliar with the region as a whole. In the same manner, through lack of knowledge of the general structural features, the practical oil man remains only partially aware of the various relationships of the "sands" from which he may be producing at various points.

L. G. HUNTLEY



FIGS. 1–3.—Geological models showing structure: 1. The Tampico oil region, modeled on the top of the Tamasopo limestone. 2. The Mid-Continent field, Kansas, Oklahoma, and Texas, modeled on the top of the Mississippian. 3. Portion of the east central states, modeled on the top of the Clinton.

DISCUSSION

CONCERNING THEORIES

Since leaving Paris last October I have been cut off from current publications and consequently have had to content myself with my old stock of theories. They have been very useful and have served me well. Their greatest value is largely due to the fact that they are easily applied and there are no contradictions. In general they all originated from a few fundamental conceptions such as the following: (1) the concentration of oil and gas into anticlinal structures or structures related to anticlinal folding; (2) the necessity, especially in new regions, of finding some surface indications such as seepages of oil or bituminous shales, before it is assumed that oil or gas is present in favorable structures. There are a number of qualifying conditions which enhance or detract from the possibilities of commercial oil and gas deposits, as, for example, the degree and extent of metamorphism, igneous activity, amount of faulting and disturbance, and the character of the possible oil-bearing formations.

In new regions where oil has not been developed commercially or in regions where only a few isolated and widely separated pools have proved to be productive it would seem that the geologist must of necessity confine himself to interpretations based on the simple and fundamental theories of oil and gas occurrence. If he attempts to apply theories arrived at by post-mortem examinations of producing fields, in areas which have been intensely studied, he runs the risk of making his own mental attitude one of doubt and uncertainty and quite unconsciously his opinions lack the stamp of conviction and finality which is necessary not only to establish his own position as a petroleum geologist but is absolutely essential if his recommendations are to be followed. And after all a geologist is employed to give definite opinions and recommendations. Doubts may assail his mind and cause him to lie awake nights but they must be pushed rudely aside when he writes his report. Whether or not a test well is to be drilled often depends upon his opinion and there can be no retraction. It is yes or no and he must stand or fall on that decision.

While this applies to geologists working in the undeveloped areas in the United States it is far more potent when the geologist is in foreign lands and especially in regions where no oil has been commercially developed. It is in such cases that the geologist must simplify his science and use only the rules and theories which have the widest applications. He cannot say we will find here commercial oil pools provided the hydraulic theory has caused the oil to migrate into high points of the fold. He must accept a theory such as the theory of the anticlinal accumulation of oil and gas and base his recommendations on this theory. If there happens to be a fault in a position which answers some pet theory of the fault advocates so much the better. If there are no faults he can

swing over to the side of the equally strong advocates of the non-importance of faults. If the folds are sharp and in Tertiary formations he is fortunate, but if they are low and gentle he can still find some writers to bolster up his faltering hopes. So in any case if the underlying strata are reasonably certain to be petroliferous and there are rocks suitable for oil reservoirs the situation resolves itself into a decision as to which is the best place for a test well and the possible depth to producing horizons.

In going over recent issues of the *Bulletin of the American Association of Petroleum Geologists* one cannot but notice the many theories advanced to account for the concentration or non-concentration of oil and gas into commercial pools, and the evidently contradictory nature of opinions expressed. The theories are based on detailed studies of producing fields or laboratory experiments and in most cases seem to require special conditions before they are operative. Some of the theories, before they could be applied, would require a diagnosis of the field after it had been drilled. The writer has no intention of belittling the value of scientific investigation but it seems there is danger of emphasizing the pure as against applied science, and after all a new theory is of doubtful value if it is not in accord with the common observations and practice of reputable geologists and if it cannot be applied to areas before they are drilled—this, of course, referring to theories of origin and occurrence. If a medical doctor of standing in the profession proposes a new treatment it must be first tried out and proved before it is generally accepted. With most of the new theories relating to oil occurrence it would seem necessary to cut the patient open before we know which theory applies.

Perhaps this criticism seems unwarranted, but one cannot escape the feeling that there is a tendency to try and beat someone to it with a new theory. It would seem that to the majority of the members of the Association the commercial viewpoint is the most essential. A theory is only of passing interest to one engaged in applied science, unless it can be applied—that is, applied in such a way as to aid actually in the discovery of new pools.

A composite statement of some of the recent theories in their relation to established theories might read as follows: "The cause of migration of oil and gas is the movement of underground water carrying with it oil and gas" and "to the extent that oil migration is controlled by the movement of water there is no theoretical reason why it should not migrate downward as well as upward." Yet "the anticlinal theory of migration and accumulation of oil and gas is based on the idea that oil and gas migrate up the dip because they are lighter than the associated water," and this "accumulation is aided by the selective segregation of oil and gas on account of their buoyancy." Having given the anticlinal theory a jolt we now pass to the causes of the movement of underground waters. We read that the "propulsive force of expanding gas has been one of the most important causes of oil migration," but we are warned that "artesian circulation must be given due weight," and are assured that "faults admit of a more or less free circulation of oil and water which results in commercial oil accumulations on structural highs," augmented by "differ-

ential pressure . . . . which has been largely responsible for the migration of oil and gas to places of accumulation." Perhaps the cause of movement is not so important because we are told that "according to the hydraulic theory oil and gas are carried with the moving waters irrespective of the original cause of water movement." If we are permitted to ignore the cause of movement it would seem that we must give some consideration to time since it appears that the "mode of accumulation depends, ... upon the rate of flow." Lest there be some misapprehension as to rate of flow we are informed that underground water has been determined to move one mile in 13 years but we are still in doubt as to whether this is rapid or slow. But why bother about time since it is only a relative matter and we find that the "migration and accumulation of oil and gas . . . . has been comparatively rapid, not the long drawn out process that is generally pictured."

Following analysis of the causes of migration and the rate of flow we may consider some of the theories relating to types of structure. We learn that "faulting is associated with and probably is the controlling structural feature of all of the oil fields in the relatively flat-lying beds of the Gulf Coast Plain" and furthermore "the displacement, the fracturing, and particularly the friction which are developed locally through faulting appear adequate substitutes for the anticlines which have more commonly been associated with petroleum accumulations," but this is qualified by the statement of a geologist of high standing to the effect that "we should not assume that faults are an essential element of accumulation for . . . . minor folds . . . . will explain the accumulation of oil" into commercial pools. However, from the many examples it would seem that the preponderance of opinion is in favor of faults.

There is abundant opportunity for the geologist not fully informed of the exceptions to new theories to go astray. For example in the Kevin-Sunburst oil field favorable structures were at first thought to be those which had steep dips and large closures but oil was finally found in structures of low dips. In the San Juan Basin, N.M., the type of fold was not the controlling factor but rather the position of the folds in relation to the topography of the basin. If we accept the theory that a given fault is the controlling factor in the concentration of oil and gas we are given considerable leeway as to whether we take the west or east side or both.

In the quite commendable eagerness to present new geologic theories relative to the complexities of oil and gas deposits, would it not be well to pause occasionally and consider the geologists who are endeavoring to make commercial application of the science. Perhaps a committee could be formed for the purpose of correlating theories and suggesting methods for field practice. It would seem that the commercial geologist needs primarily to keep in mind the relation of the science of geology to the work he is required to do. In fine, the petroleum geologist is continually called upon to answer a question of commercial importance and he must look to geology for the answer.

FRED B. ELY

REVIEWS AND NEW PUBLICATIONS

The Study and Correlation of Sediments by Petrographic Methods. By HENRY B. MILNER. The Mining Magazine, February, 1923.

This paper on the application of petrographic methods to correlation of sediments must be of interest to oil geologists, for they are undoubtedly more keenly alert to recognize and use methods that will permit definite and rapid correlation than are any other geologists. Correlation of well records is always difficult for conscientious workers, and correlation of surface strata is often impossible unless the geologist is helped either by petrography or by paleontology. There are regions where neither the fossil faunas nor the easily discernible characteristics of the rocks will justify attempts to correlate isolated outcrops. A method that opens a new avenue of attack is sure of a welcome because it is so badly needed. Of course petrography will also doubtless fail in many instances, but, as Milner points out, "petrographical methods of correlating sediments represent . . . . a useful method of attack in stratigraphical problems where the normal paleontological evidence is obscure or totally lacking."

In sedimentary petrography, just as in other branches of geology, reliable results come only with training and thoroughness. Superficial observations will be as treacherous as are careless fossil identifications, and accurate correlation will take more than ability to identify a few minerals by petrographic methods. Milner states that "just as no careful stratigrapher is content to refer to every oyster-like fossil he finds as *Ostrea* without endeavoring to fix both genus and species of the organism . . . . so no investigator is justified in the indiscriminate use of the few name labels we do possess in sedimentary petrology, without seeking to know his deposit so thoroughly that his identification and description of the rock types are technically accurate. To know a sediment thoroughly, in the widest petrological sense, is to know its origin, nature, mode of derivation, mineralogical composition, internal and external structures, lateral and vertical variations, mechanical analysis, porosity and permeability, quite apart from the organic remains that may be present." Plainly this is no program for the man who can study 50 samples of drill cuttings in a day. Nor can it be successfully conducted by one ignorant of degradational and aggradational processes, for elaborate determination of fact means little if the significance of the fact is not understood.

In one respect the task of the petrographer who works with sediments seems decidedly more simple than that of the paleontologist, for instead of thousands of forms, he must familiarize himself with a comparatively small number. Milner lists 54 minerals which he states may be expected to occur

more frequently than others in sediments, and of these 13 are designated as very rare. Furthermore he states that "under normal conditions the number of different mineral species occurring in sediments is not great; possibly 25 is a fair average for detrital deposits." For most work the number of minerals that must be considered may be greatly diminished by discarding all that have a specific gravity less than that of bromoform solution, which is 2.90. "An investigation of the petrography of certain sediments . . . . has conclusively shown that for limited areas . . . . horizons are broadly characterized by heavy mineral assemblages." Milner does not claim that long distance correlation may safely be based upon similar assemblages of the heavier minerals, but it is obvious that by a series of short range correlations any desired distance could be covered.

Milner suggests that petrographic methods may advantageously be applied to oil field problems, for correlating outcropping strata, for correlating beds that are sampled through shallow prospect pits, or deeper strata that may be penetrated in wells drilled for oil. The reviewer is confident that there are many areas in the oil-yielding parts of the United States where petrographic work will yield results of great scientific and economic importance. In regions without outcrops contacts between formations may be located and traced by petrographic work on samples from shallow holes with resultant discoveries of irregularities in the trend of the contact, that may indicate anticlinal folding or other economically significant structural feature. In western Oklahoma and areas of similarly obscure stratigraphy and structure where shallow holes bored with core drills into the red-beds may fail to cut any bed so unique in color or composition that it may be readily recognized if it is encountered in some near-by hole, it is far from improbable that thin layers with distinctive aggregates of heavy minerals may be recognized wherever they are penetrated in restricted areas. In all oil fields petrographic study of drill cores and finer drill cuttings must inevitably reveal characteristics that will sometimes permit definite correlation where paleontologic data are lacking, and will always assist in making correlation definite, as well as yielding indirect returns of great value through the acquaintance with oil-field sediments that must inevitably follow such work.

K. C. HEALD

THE ASSOCIATION ROUND TABLE

FOR THE ENCOURAGEMENT AND GUIDANCE OF ASSOCIATE EDITORS

An associate editor has written asking me whether the Association wants its associate editors merely to read proof, solicit contributions, and the like, or whether it wants the associate editors to edit.

There can be no doubt as to the answer. As stated in the last issue, the *Bulletin* is the most universal and most lasting expression of the Association's activities. It should be the pride of each member. The duty of making and keeping it such that it will be a source of pride and gratification falls almost entirely on the editorial staff. It follows that the editors and the associate editors can scarcely go too far in seeing that each paper published in the *Bulletin* is well written, well phrased, and well presented, free alike from errors in grammar, inaccurate statements, and inadequate treatment of the subject-matter. In short, the Association expects its editorial staff to edit.

The associate editor whose letter I have suggests that an editor should do five things, as follows:

1. Conserve space. If an article can be shortened without losing clearness or readablity it should be done.
2. Eliminate ambiguity. Any phrase that is ambiguous should be altered.
3. Promote clearness. A phrase that is not clear should be called to the writer's attention, preferably with the editor's interpretation as a suggestion.
4. Rectify incorrect usage of words. Any word that is incorrectly used should be deleted and the correct word substituted.
5. Correct imperfect grammatical construction.

If every editor tactfully and thoughtfully follows these rules he is entitled to the thanks of each member of the Association, including those members whose papers he edits.

If therefore, editors and associates, sometimes you receive curses instead of blessings, remember that a tree is known by its fruits and a scientific association by its publication, and that the *Bulletin* is pretty nearly the biggest and finest thing our Association does.

MAX W. BALL

LET'S TALK OF HOUSTON

The California meeting has come and gone, and our minds are turning to the annual meeting in Houston on March 27, 28, and 29.

We had a wonderful time in California. The field trips, which included an all-day trip through the Los Angeles Basin fields Friday, an all-day trip

through the Ventura fields Sunday, and, for those who could stay over, four days in the San Joaquin Valley, on Monday, Tuesday, Wednesday, and Thursday, gave us a look at practically every important field in California except Huntington Beach. These trips were run off with amazing smoothness and promptness, and were so arranged that everyone was kept fully informed on the geology of everything he was seeing. Incidentally, they furnished a great opportunity for acquaintance and fellowship.

The program was loaded with information about the California fields, and some others besides. The California men opened up their storehouses and poured out more information than we could carry away. If ever Association spirit was evident, it was evident in the energy, the hospitality, and the generous spirit of the California meeting.

Before the California meeting was over Houston had been selected as the next meeting place, and plans were already far advanced for making the Houston meeting even better, if possible, than that at Los Angeles. Wichita and Ardmore had been strong contenders, but the scope and variety of program promised by the Houston sponsors completely overcame the executive committee. Even the Mid-Continent and Rocky Mountain men, who had gone to the meeting favoring Wichita, were most of them pulling for Houston before a decision was reached.

Because there was so much for the rest of us to learn about California, the California program was chiefly descriptive, with very little of a controversial nature. It is hoped to swing the Houston program to the other extreme, laying the emphasis on theoretical and even controversial matters. For instance, there is to be a half-day's symposium on salt domes, a subject which usually provokes controversy enough for the most belligerent, and perhaps a symposium on the occurrence of oil in atypical structures (meaning structures other than closed anticlines), with theories as to the reasons therefor. We expect a paper on the origin of oil, giving the results of a series of experiments on the actual transformation of oil-forming material into oil, under varying conditions of heat, pressure, and moisture. And we hope to have other papers by some of our big men on general theories of origin and accumulation.

Descriptive papers will not be neglected, for, owing to Houston's location, we should be able to have a few papers on the fields of Latin America. We hope, by the way, that all the Latin-American geologists who ordinarily find our meetings too remote to attend will find it possible to be at Houston, giving us a chance for new and renewed acquaintance, and for new voices on the program.

If you have ideas regarding the program, or the conduct of the meeting, or if you have a paper to present, write to Alexander Deussen, 504 Stewart Building, Houston, Texas, chairman of the committee on arrangements for the meeting, working under John R. Suman, regional director for the Gulf Coast. And begin now to make your plans for the meeting. It is only a few weeks away.

Don't overlook the fact, by the way, that an increasing number of oil-company executives, from company presidents down to department and section heads, are attending our meetings and finding them very profitable. If you work for a company see that its executive and administrative officers are given a cordial invitation to come to Houston.

MAX W. BALL

OIL RESERVE IN TEAPOT DOME, WYOMING

Editor American Association of Petroleum Geologists

DEAR SIR: The geologists engaged in the Teapot investigation for the Senate Committee on Public Lands have expressed the opinions that the reserves of oil in the Teapot Navy Reserve below the Second Wall Creek are "problematical," "that it is impossible to assign any value to these sands," and "in my opinion the possibilities from these sands are not attractive." That the inclusion in the lease of the reserve in the deep sands was not commented on shows how negligible the reserve was thought to be. Since geologists have come in for so much criticism by operators for regional underestimates, I wish to enter a disclaimer to the effect that the Teapot dome will probably produce from below the Second Wall Creek sand a reserve in excess of one-fifth of the average reserve given the Second Wall Creek sand by the geologists in question. This reserve is of especial importance since in large part it would not have been produced till it is needed much more than now.

Respectfully yours,

ROSWELL H. JOHNSON
Professor of Oil and Gas Production
UNIVERSITY OF PITTSBURGH

REPRESENTATION IN THE AMERICAN PETROLEUM INSTITUTE

At the St. Louis meeting of the American Petroleum Institute in December, Alexander Deussen was elected to the Board of Directors of the Institute to represent the Association. Thus, for the first time geology is officially recognized as an integral part of the oil industry and accorded a seat at the industry's council table.

The unanimity of this recognition by the leaders of the industry is shown by the fact that out of 110 nominees for 11 vacancies Deussen received the third highest number of votes on the first ballot.

MAX W. BALL

THE INTERNATIONAL PETROLEUM EXPOSITION

The accompanying photograph shows a part of the educational exhibit of the International Petroleum Exposition and Congress held in Tulsa, Oklahoma, October 8 to 14, 1923. The exposition was conceived and carried out with the idea of drawing together the various branches of the oil industry and of introducing to all those connected with the industry, and to the public at large, the nature of work involved in the finding, producing, refining, and marketing of petroleum and all of its products. The exposition in its first year was a decided success and will undoubtedly be carried on as an annual event.

The geological exhibits were grouped in the general educational exhibit of the exposition. Among these exhibits were those of the United States Geological Survey and the Bureau of Mines section of Bartlesville, Oklahoma. Both of these were extremely interesting and educating to all those who saw them. The larger part of the exhibit was arranged for by the geologists of Tulsa, who represented the Tulsa Geological Society which also acted as the representative of the American Association of Petroleum Geologists, and the mid-continent section of the A.I.M.E. Committees from these two bodies secured maps, cross-sections, literature, photographs, fossil collections, peg models, cores, rock specimens, and various other geological data that would be of interest or of educational value to the oil operator and the general public. From the interest shown in the exhibit by the crowds attending the exposition, we feel that we succeeded in our first attempt at an exhibit of this nature.

The material for the exhibits was obtained from the various state surveys, universities, oil companies, and individuals who were willing to contribute. Among these were the Geological Survey of Illinois; the geological department of the Atlantic Oil Producing Company of Dallas; the Rolla School of Mines, Rolla, Missouri; and the Bureau of Mines of California. The Atlantic Oil Producing Company booth (see accompanying photograph) had an excellent exhibit on the microscopic study of well cores and the results that can be obtained in this work. Mr. Whitehead and the geological department of the Atlantic Company deserve a great deal of praise for the thoroughness with which they carried out their ideas of showing the oil operator and driller the importance of obtaining and preserving valuable geological data. We hope that next year we can obtain more of this material. The idea of the geological exhibit is to show the results of geological work in connection with the finding and producing of oil. While geology is no longer an experiment with the oil companies and operators, it is still necessary to show results obtained from new studies, and we believe that these exhibits will furnish the geologists an opportunity to present these ideas and results to those most interested in their work.

RICHARD HUGHES

EDUCATIONAL EXHIBIT OF THE INTERNATIONAL PETROLEUM EXPOSITION

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following applicants for membership in the Association. This publication does not constitute an election, but places the names before the membership at large. In case any member has information bearing on the qualifications of these applicants, please send it promptly to Charles E. Decker, Norman, Oklahoma.

(Names of sponsors are placed beneath the name of each applicant.)

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Corrected to February 8, 1924

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Staggs, Olan B., Box 2022, Tulsa, Okla.
Stahl, William J., 701 New Masonic Bldg., Bartlesville, Okla.
Stanley, M. Wood, P. O. Box 441, Dallas, Tex.
Stein, Ira H., Cherokee, Okla.
Stilley, Earl M., Empire Gas & Fuel Co., Bartlesville, Okla.
Stipp, Thomas F., Associated Oil Co., Fellows, Cal.
Stone, Jeptha C., Address unknown
Stoner, Oscar E., Box 658, Okmulgee, Okla.
Suman, George O., Jr., Associated Oil Co., Oil Center, Cal.
Teas, Paul C., Box 561, Norman, Okla.
Teets, D. D., Jr., 813 Indiana Ave., Charleston, W. Va.
Thompson, T. C., Box 1260, Okmulgee, Okla.
Thralls, Warren H., 422 Union National Bank Bldg., Wichita, Kan.
Trainer, David W., Jr., McGraw Hall, Cornell University, Ithaca, N. Y.
Turman, Arthur F., Drawer J, Whittier, Cal.
Tweedy, Joseph L., Box 419, Dallas, Tex.
Tygrett, Howard V., Route 1, Bowling Green, Ky.
Upham, Harry, Mineral Wells, Tex.
Van Dall, John E., 601 Delaware, Bartlesville, Okla.
Waldo, Kenneth C., 952 Colbert Ave., Oil City, Pa.
Warner, J. L., 153 N. Grant St., Casper, Wyo.
Watkins, William A., 626 Stewart Ave., Ithaca, N. Y.
Watson, Joseph D., 2543 East 11th St., Tulsa, Okla.
Webster, Hugh B., Standard Oil Co., Standard Oil Bldg., San Francisco, Cal.
Weinzierl, John F., Geol. Dept., Marland Refg. Co., Ponca City, Okla.
Weirich, T. E., Marland Refg. Co., Geol. Dept., Ponca City, Okla.
Wendeln, O. B., Pure Oil Co., Columbus, Ohio
West, Joe W., 217 E. Boyd, Norman, Okla.
Westby, Gerald, 1549 St. Paul St., Denver, Colo.
Wheeler, Carlton W., Box 749, Roxana Corp., Ardmore, Okla.
Wiest, Frank C., care of J. W. Merritt, 312 Atlas Bldg., Tulsa, Okla.

Wilshire, L. M., 938 Vermont St., Lawrence, Kan.
Wilson, John H., Midwest Refining Co., 934 First National Bank Bldg., Denver, Colo.
Wilson, J. M., 305 Ward Bldg., Dept. of Conservation, Shreveport, La.
Wolff, Deane J., Box 456, Pecos, Tex.
Wright, Andrew C., 909 Giddings Lane Bldg., Shreveport, La.
Wright, Mary E., Address unknown
Wuensch, C. E., 5 Nassau St., care of A. J. McAllister, New York City, N. Y.
Wylie, James R., Jr., 424 Whitney Ave., Wilkinsburg, Pa.

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

H. D. MISER, of the U. S. Geological Survey, is working on a geological map of Oklahoma, with headquarters at Norman.

F. W. DEWOLF is with the Boyd Oil Company, 1320 Kirby Building, Dallas, Texas.

HARRY W. BELL has changed his address to Shreveport, where he is Supervisor of the Minerals Division of the State Department of Conservation.

MRS. FANNY EDSON is spending the year at Palo Alto, California, where she is doing work leading to the Ph.D. degree at Stanford University.

The bulletin of the Association is in demand in foreign countries, as well as having a large subscription list in this country, individuals, oil companies and libraries making up the list. Among the foreign subscribers are the following: Société Anonyme D'Exploitations, Strasbourg, France; New Zealand Geological Survey, Wellington, New Zealand; Secretaria de Industria, Mexico; The University Library, Manchester, England; Geological Investigation Department, Mirbakhaeva, Russia; Direction des Mines, Boryslaw, Poland; Dr. Otto Gutzwiller, Bremgarten, Switzerland; I. Omura, Nippon Oil Co., Tokio, Japan.

HAROLD W. HOOTS has a fellowship at Stanford University.

W. W. SCOTT, until recently stationed at Shreveport, Louisiana, is now in charge of the Dallas, Texas, office of the U. S. Bureau of Mines. Mr. Scott has supervision throughout the southwestern district which includes Texas, Louisiana, and Arkansas.

H. W. BELL, P. S. HAURY, and R. B. KELLY of the U. S. Bureau of Mines have completed their report on "The Eastern Part of Smackover, Arkansas, Oil and Gas Field." The report is published by the Arkansas State Bureau of Mines, Manufactures, and Agriculture, Little Rock, Arkansas.

WALLACE PRATT, of the Humble Oil and Refining Company of Houston, Texas, visited the Shreveport office of the company in December.

EUGENE HOLMAN, division superintendent for the Humble Oil and Refining Company at Shreveport, Louisiana, was married, November 22, 1923, to Miss Edith Carver Reid at Hattiesburg, Mississippi.

C. A. FISHER, president of the Rocky Mountain Association of Petroleum Geologists, and Mrs. Fisher entertained the members of the Association and

their ladies at their home at 314 Franklin Street, Denver, Colorado, on November 30. A mock trial, fake telegrams, singing, dancing, and Mah Jongg contributed to a most pleasant evening.

The Rocky Mountain Association of Petroleum Geologists, at its bimonthly meeting Thursday, December 6, elected the following officers for the coming year: Thomas S. Harrison, president; Carroll H. Wegemann, first vice-president; F. F. Hintze, second vice-president; Charles M. Rath, secretary-treasurer.

E. M. PARKS, who has been in California for two years, has opened consulting offices in the First National Bank Building, Denver, Colorado.

JAMES M. DOUGLAS, geologist for the Union Oil Company, is spending most of his time at Fort Collins, Colorado, in the vicinity of the company's new Wellington well.

C. J. HARES, chief geologist of the Ohio Oil Company, is in Denver frequently of late. His home is in Denver but his headquarters are in Casper, and he is usually at neither place.

A. T. SPRING and C. A. FISHER are competing for leases on the Berthoud structure, Colorado, a structure which Mr. Spring discovered when on the geologic staff of the Roxana Petroleum Corporation.

JOSEPH H. SINCLAIR is returning to New York City from the Republic of Guatemala where he has been making geological examinations of prospective oil territory.

J. B. KERR, who was mapping field geology in Arkansas and Louisiana for the Standard Oil Company of Louisiana the past year, has moved to California, where he expects to continue geological work.

J. M. WILSON is situated in Shreveport, Louisiana, with the Minerals Division of the Louisiana State Conservation Department.

ROBERT S. BURG, of Fort Worth, Texas, was in Shreveport, Louisiana, in November.

ORVAL L. BRACE, of Camden and El Dorado, Arkansas, and Miss Myrtle Germany were married in October and went to the Pacific Coast on their wedding trip.

LEE HAGER, LEON F. RUSS, and WALTER L. GOLDSTON were among interested visitors from other states at the recent wild-cat tests in Union Parish, Louisiana, in October.

EDWIN B. HOPKINS, of New York City, made a short visit to Shreveport, Louisiana, in November, prior to one of his many trips to Venezuela.

ARTHUR L. ARNOLD has left the employ of the Atlantic Refining Company, Pittsburgh, Pennsylvania, to make his headquarters on the Pacific Coast.

At the annual meeting of the Tulsa Geological Society held on January 5, 1924, the following officers were elected for the ensuing year: *President*, FRANK C. GREENE; *Vice-President*, J. C. ROSS; *Secretary-Treasurer*, GEORGE A. KROENLEIN; *Council:* R. S. MCFARLAND, W. B. WILSON, L. H. WHITE, and RICHARD HUGHES.

VIRGIL A. THOMPSON is working in Maracaibo, Venezuela.

ROBERT N. KOLM, with the Atlantic Oil Producing Co., has been transferred from Dallas to Wichita Falls, Texas.

HOYT S. GALE is now located in Los Angeles where he is getting acquainted with southern California geology. Gale is building a home in Eagle Rock, a suburb of Los Angeles.

WALTER A. ENGLISH has temporary headquarters at Taft, California, where he is carrying on detailed geologic work for the Standard Oil Company, of California.

After a rather long interval, the Branner Club is now holding its regular meetings. CLARENCE B. OSBORNE discussed the Kevin-Sunburst field of Montana on the evening of January 17. The new officers for this year are: H. R. JOHNSON, president; ALFRED O. WOODFORD and C. R. MCCOLLOM, vice-presidents; WAYNE LOEL, secretary-treasurer; and PAUL HENDERSON, assistant secretary-treasurer.

E. CALL BROWN has gone to New Zealand on economic oil work.

A subcommittee of the American Association for the Advancement of Science is now working in Los Angeles under the chairmanship of ROBERT T. HILL to place appropriate signs at places in the county having particular geologic interest so that these natural phenomena will be brought to the attention of all.

W. E. WRATHER has been in southern California this winter.

ELTON RHINE, geologist, until recently manager of the Shreveport, Louisiana, office of the Amerada Petroleum Corporation, has resigned to enter the automobile business at Texarkana, Arkansas.

W. C. SPOONER, who has been chief geologist for the Arkansas Natural Gas Company at Shreveport, Louisiana, resigned January 1, 1924, but will retain his present office in the Ardis Building for consulting work.

H. V. HOWE, professor of geology at Louisiana State University at Baton Rouge, presented a paper on "The Oligocene of Louisiana" before the Shreveport Section of the Southwestern Geological Society, January 4, 1924.

CLARENCE B. OSBORNE, who for the past five years has been doing geological work in the Rocky Mountain region, part of which time he was in charge of the geological work of the Midwest Refining Company, of Denver, and the Homestake Exploration Company, of Montana, has opened offices at 402 Security

Building, Los Angeles, California, for the purpose of doing consulting work. He has been made general manager of the Olig Crude Company, of California, one of the old small producing companies.

JOSEPH T. SINGEWALD, JR., professor of economic geology at the Johns Hopkins University, and LINCOLN ELLSWORTH, of New York, sail for Peru in February to carry on geologic explorations in the Andes of Central Peru. The expedition will be known as the "Ellsworth Expedition." The collections of geologic materials that are secured by the expedition will be worked up at the department of geology of the Johns Hopkins University.

W. W. MCDONALD has resigned his position with the Atlantic Oil Producing Company to join the geological department of the Louisiana Oil Refining Corporation at Shreveport, Louisiana.

LEON J. RUSS, who has charge of Frankel Brothers' interests in Louisiana and Arkansas, was a recent visitor in Shreveport, Louisiana.

R. R. THOMPSON of the T. & P. Coal and Oil Company at Thurber, Texas, was in Louisiana in January. The T. & P. Company drilled a gas well late last year in wild cat territory near Mansfield west of the De Soto–Bull Bayou field.

A. E. HARTMAN, of Fort Worth, Texas, was in Shreveport last January, renewing acquaintances of Homer boom days in Louisiana.

HAROLD W. C. PROMMELL of Denver, Colorado, left on October 5 for South America, where he will be engaged in consulting work which will extend through Brazil, Argentine, and possibly Venezuela.